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Electric Power on the Farm

BY
Adolph Shane

AMES, IOWA

Engineering Experiment Station

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ELECTRIC POWER ON THE FARM

BY ADOLPH SHANE

INTRODUCTION

Conditions change as the years pass. What was satisfying ten years ago is not altogether agreeable now, our demands growing with the times. This is particularly true of the farmer, who just now is, in some measure, reaping benefits from conditions which to nearly all other people represent higher cost of living. As a result he desires more of the conveniences and comforts of urban life.

One of the most effective forces tending to increase the enjoyment of life on the farm by lessening the labor incident to farm and household operations is the use of electric power for pumping, churning, grinding, etc.; for lighting the house and barn, and for such purposes as ironing, washing, and other domestic uses in the home. It is the purpose of this paper to outline an electric system of general application, and to discuss in some detail a particular installation, for which purpose certain farm conditions have been assumed. This is to serve as a guide for other similar installations.

Some of the advantages of electric power are mentioned in the following paragraphs.

It tends to make the farmer more independent of outside help and unfavorable weather conditions.

Since an electric motor usually needs no special foundation, it may rest on the floor, or on a truck for portability, or may be fastened to the ceiling or wall, with equal facility. This means flexibility as to application about farm buildings which are necessarily more or less scattered.

Electrical machinery is cleanly, occupies small space, requires little attention, is easily controlled, and when a building is properly wired, does not add to the fire risk. Emphasis is laid on "properly wired", for, whereas the correct wiring of a house or barn adds little or nothing to the danger from fire, a poorly wired structure may be a real fire risk.

The use of electric power for domestic purposes may prove quite economical aside from its convenience. Consider, for example, the flat iron. Ordinarily, if no gasoline range is at hand, the housewife burns coal in the kitchen range, warming up the entire mass of the stove, not to speak of the heat dissipated into the kitchen, merely to heat the small surface of the iron. Here the relatively *cheap* heat energy in the coal is used very wastefully; a large part of it, to start with, goes up the chimney and a little, a very little of what is left, finally penetrates the flat iron. On the other hand, the rather *expensive* heat produced by the electric energy is *all* utilized in the small mass of the flat iron. In other words, one hundred per cent of the electric energy at the iron is converted into heat; and this all goes to warm up the flat iron, just where the heat is desired and nowhere else. Further, the moment the switch is turned off, the supply of heat ceases, while in the case of the coal stove, the supply of fuel already ignited, must first be consumed. Thus, in the final analysis, the difference in cost is not as great as might be supposed. During the summer months the advantage of the cooler kitchen with the electric iron needs no comment.

With the popularization of the use of electric power in the home came the vacuum cleaner, which eliminates the labors of spring and fall house cleaning, and keeps all rooms clean and sanitary every day in the year with comparatively little labor. A carpet or rug, for example, may be cleaned more effectively in a few minutes with a vacuum cleaner than in an hour or so by the process of beating. Suction permits of this without raising any dust.

Electric lighting is an attractive method of illumination because, with the use of the modern high efficiency lamps, the cost is not great, and it is safe and convenient. With properly arranged circuits the light is instantly at one's command and no groping in the dark is necessary to secure it. This method of illumination is especially advantageous to the farmer in that it permits lighting the barn and other buildings of inflammable character, in a safe and efficient manner.

In considering the application of electric power to farm purposes, the question arises as to how far or how completely should such an electrification be extended. The answer varies considerably under different circumstances. If the farmer is fortunate enough to have a transmission line passing within striking distance of his property, which could supply him with an unlimited amount of cheap power instantly at his command, the possibilities are very wide. He would have not only light at his disposal, but also economical power for large portable motors to run threshers and ensilage cutters, down to the very smallest units. He would not be compelled to start and stop engines, the mere movement of a handle being sufficient to start his machinery. Repairs would be light on the electric apparatus, and failure of power would seldom occur.

If a farm is very large and the demands for power are large and various so that a considerable load would remain on the generator for long periods of time, an extensive electrical scheme might be carried out with profit even though it might be necessary to generate the power on the premises.

Again, if a stream is on or near the farm, which can be developed into a reliable source of water power at a reasonable cost, the harnessing of this power to an electric generator would afford, at a very small cost and attendance, all the advantages inherent in electric driving of machinery and electric lighting.

Where the farm is only of average size, and has neither water power nor the advantages of a nearby transmission system, recourse must be had to an engine for the driving of the generator. In this case enthusiasm should be tempered with judgment to secure a safe, reliable, and economical installation.

It scarcely seems advisable to the writer, under such conditions to install a plant big enough to supply power to a large motor connected to a thresher or to a high power ensilage cutter: for this would necessitate a large increase in the cost of a plant which on all except a few days in the year would be running far under capacity. Consequently it would be inefficient and wasteful of fuel. To get the most economical service from a private plant, it should have a good load during the time it is running. In other words, the smaller and consequently the less expensive we desire a plant to be, the more nearly should the average load approach the capacity of the plant. To this end, a schedule should be arranged for the time of operating the various motors and charging the storage battery. If this schedule is properly arranged and adhered to, the size of plant needed for any particular farm will be as small as possible.

A storage battery consists of a number of glass jars, or cells, each of which contains treated lead plates immersed in dilute sulphuric acid. The battery may be charged by the current of a generator. It may then furnish the power for lights or other electric appliances, when the generator is not in operation.

Either a steam or gasoline engine may be used as the source of power, but for a small private plant the gasoline engine offers the most advantages. There is no boiler or steam piping required, so the plant is considerably less expensive as to first cost, and occupies much less space. The gasoline engine requires but little attention and is economical as to fuel.

In considering the extent to which electrification may be justified the following line of reasoning is suggested. It is assumed that the farmer desires electric light. This means a small gasoline engine and generator. When the engine is not running the generator, it may drive a line shaft belted to small power machines which are fixed in place. But if another and larger portable engine is required for other purposes, then the size of the plant should be increased somewhat, and an electric motor installed instead of the second engine. The generator will then have sufficient capacity when the large motor is not in use to take care of any small motor load in the house, such as fan and washing machine motors, a flat iron, and perhaps even a small ice plant in the basement run by a half horsepower motor.

The grindstone and emery grinder in the repair shop, and the churn and cream separator in the creamery, are machines suitable for connecting to the line shaft. The other pieces of machinery vary in power and number on different farms, but the following will be considered here:

Husker and Shredder	6 horse power
Corn Sheller	4 horse power
Feed Grinding Mill	6 horse power
26-inch Tilting Table Saw	4 horse power
Elevator (to crib)	2 horse power
Pump	1 horse power

If a windmill is ordinarily used for pumping water, a motor would be needed only during long periods of calm weather or when the windmill is being repaired.

SOME ELECTRICAL FACTS

A few elementary statements underlying electrical phenomena are here given to aid in the correct installation and operation of electrical machinery.

Some substances conduct the electric current, others do not. Those of the first class come under the head of *conductors,* the second class under the head of *insulators.* The following lists represent some of the materials in each class.

Conductors	*Insulators.*
Metals	Mica
Carbon	Paraffine
Salts in solution	Glass
Sulphuric acid	Rubber
	Marble
	Slate

There is a third class of materials that is intermediate between these two. That is, they are poor conductors, but not very good insulators. Water in its natural state comes under this head, and because of the uncertain elements connected with the conductivity of water and its deteriorating influence on insulation, dampness about electric circuits should be scrupulously avoided. Copper is one of the very best electrical conductors, and because of its moderate cost is extensively used for wiring circuits. Rubber compositions are considerably used for wire insulation while slate or marble affords good switchboard material. There have lately been put on the market panels made of composition materials which have considerably reduced the cost of switchboards.

A source of electric power must have two wires leading from it to form a "circuit". Where the current always flows in the same direction, one is known as the *positive* (+) wire and the other the negative (—) wire. This is known as direct current as constrasted with the alternating current, where the current rapidly alternates in the wire, flowing first in one direction and then in the other. But whatever the system, two conductors are always required. In certain instances but one wire is apparently used, such as in an electric railway system using a trolley wire. But here the ground or track acts as the other wire. It is sufficient for practical purposes to consider the current as flowing out of the positive wire through the lamp or motor and back by way of the negative wire. But one wire connected will not light the lamp nor run the motor. Exactly as much current returns via the negative wire as goes out of the positive wire. Just as pressure must be present in water pipes to cause water to flow, so also must there exist an electric pressure to produce the electric current. In a given electric circuit, doubling the pressure doubles the current and halving the pressure halves the current. The unit of pressure is called the *volt*, the unit of current the *ampere*.

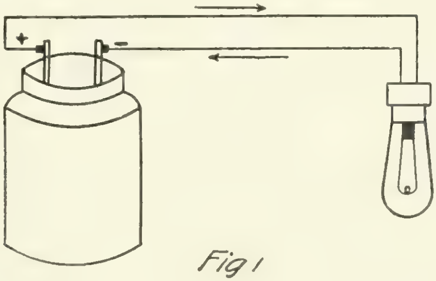

Fig 1

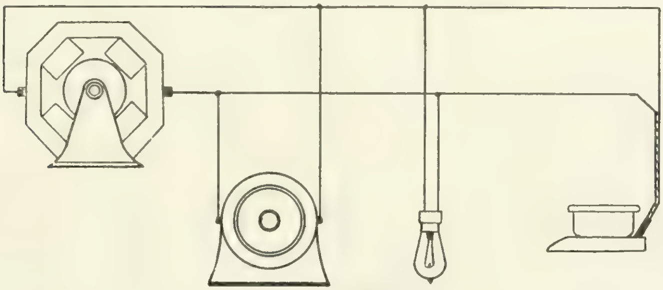

Fig. 2

Consider an electric battery (Fig. 1) connected to a small electric lamp. The current starts at the carbon or positive (+)

terminal and flows towards the lamp, passes through and heats the filament, causing it to glow, and returns to the zinc or negative (—) terminal of the battery. The amount of current that flows through the lamp depends on the voltage of the battery. If the voltage is not high enough the lamp will burn dimly; if too high, it will give an excellent and highly efficient light but the lamp will not last long. If another size of lamp be connected to the same battery, a different current will flow depending on the electric *resistance* of the lamp, just as a small water pipe offers greater resistance to the flow of water than a larger pipe, thus allowing a smaller quantity of water to pass out. So it is worth remembering that with a given lamp, the current depends on the voltage, while for the same *voltage* the current depends on the amount of resistance connected to the circuit. It is noticed that lamps of small and large candle-power are often connected to the same mains. This merely means that each lamp was manufactured for that particular voltage. Of course the larger lamp has less resistance and allows more current to flow, which produces more light. But this does not necessarily shorten the life of the larger lamp, since the filament is coarser to accommodate the greater current.

A dynamo may be substituted for the battery with like results and is usually the source of electric power where a considerable amount is used, since the cost of large amounts of power from primary batteries makes their use prohibitive. It is also clear that more than one lamp or more than one motor may be connected to the leads or mains from the generator, each one taking its due share of the current so long as the voltage does not change. This is known as the parallel system of distributing electric energy and is the most common method used. Fig. 2 illustrates this scheme.

Storage batteries are conveniently used in connection with generators in order that power may be at hand when the generator is not running. These, unlike the common primary battery, are efficient, reliable, and, if well taken care of, last a long time. Of course, they must be regularly charged to replace the energy supplied by them.

The writer advises the use of the storage battery in connec tion with private plants for lighting and for fan and sewing machine motors, which consume but little power. Sufficient battery capacity may be provided to permit these small motors to run in the day time when the engine is not in use. The generator usually will not be run at night, and during the day it can furnish all the necessary power for pumping, churning, grinding, cream separating, etc., as well as for charging the battery for night service. This use of the generator in the day time reduces the size and consequent cost of the battery, yet power is not cut off in the home or barn, for the battery supplements the generator service at night.

THE SYSTEM

Where the purpose of electric power is for lighting only, a 30-volt or 60-volt system might be employed, thus reducing the number though not necessarily the expense of storage cells. But where electric power is to be utilized to a considerable extent for running motors, as for example on the farm where the power used for lighting is less than that used for motive purposes, the writer recommends the standard 110-volt system throughout. This assumes that the longest distance of transmission does not exceed 500 feet, which ought to be the condition on the average farm. Special conditions might require even a higher voltage. Some of the reasons for the choice of the 110-volt system in preference to a lower one are: (a) There is greater simplicity. The power motors should preferably be for not less than 110 volts to avoid increased cost of conducting wires. A double voltage scheme would be required if the lower lighting voltage were employed. (b) The cost of the entire installation is not materially different. (c) Any lamp, motor, or other electric appliance may be used as well on one circuit as another. (d) Standard apparatus and repair parts are more easily secured.

There are now a number of styles of generator sets on the market, some of which are belt driven, and others, which are generally more expensive, are direct coupled. Because of its lower first cost, the belt driven engine-generator set will, no doubt, prove more popular. But it must be remembered that the belt requires some attention and it also needs occasional

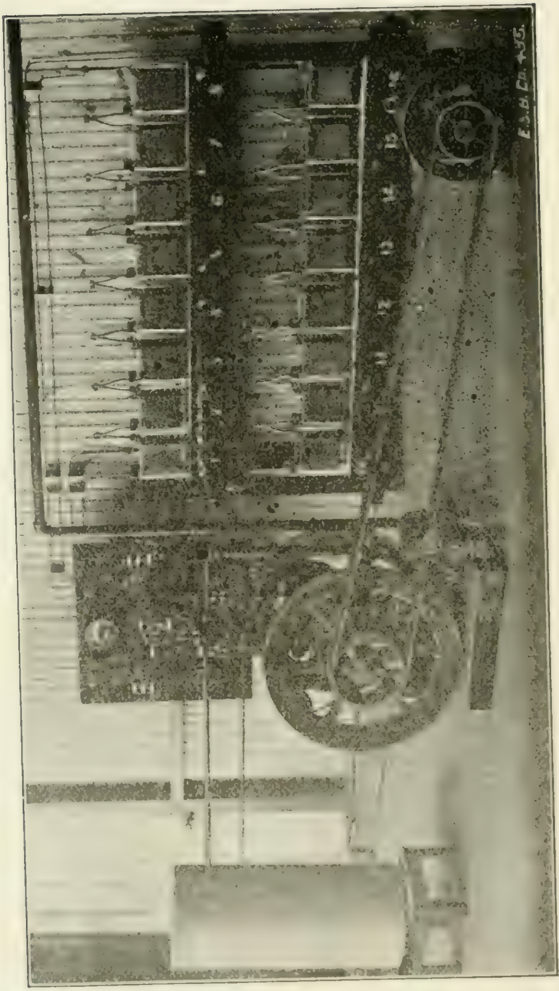

Fig. 3—Typical Small Generating Plant

renewal. However, the particular installation outlined in this paper will be of the belt driven type.

The installation will then consist of

(1) Gasoline Engine with accessories.

(2) Dynamo for the production of electric power.

(3) Storage battery to supply power when dynamo is not running.

(4) Switchboard with necessary wiring, to control dynamo and battery.

(5) Main wires or leads from switchboard to house, barn, etc.

(6) House and barn wiring.

(7) Motors of different capacities together with lamps and appliances as needed for the particular purposes.

Fig. 3* illustrates a small generating plant including storage battery equipment, and gives an idea of the space taken up by such a unit.

In order to determine the necessary capacity in such an installation, it will first be necessary to estimate the maximum probable connected load at any one time; then with the use of a little judgment, the capacity of plant may be determined. Fortunately such capacity is not measured by the total horsepower of motors installed plus storage battery capacity, since at no one time is it probable that *all* motors and other loads are in use. So a considerably smaller generating outfit than would be indicated by the total capacity of connected motors may be installed and will give satisfactory service.

THE HOUSE INSTALLATION

Lamps, Shades, and Fixtures. There are today three types of incandescent lamps on the market. The carbon filament, tantalum filament, and tungsten filament lamps. The tantalum lamp has an efficiency somewhat under twice that of the carbon, while the tungsten filament offers an efficiency of three times that of the carbon. The carbon lamp is the cheapest in first cost, while the tungsten is the most expensive of the three types. Yet where a lamp is burned a considerable time each day, it is advised to use the tungsten lamp because of its high economy. Putting it another way, the tungsten lamp for the same amount of light takes about a third the electric energy consumed by the carbon lamp, thus reducing the size of the storage battery as well as saving fuel at the engine. The tungsten lamp, however, should not be hung from a lamp cord, unless it is equipped with a keyless socket and the lamp is well out of the way. The filament is rather fragile and the use of a keyless fixture fastened to a firm support is better practice. This with a wall switch to control the lamp will tend to avoid accidental jar which might rupture the filament. Tungsten lamps under these favorable conditions ought to have an average burning life of from 800 to 1000 hours. The objection to

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* The cuts for several of the illustrations in this bulletin have been kindly supplied by certain manufacturers. These have not been inserted for advertising purposes. There are a number of reputable establishments which are ready to supply the needs for private electric installations.

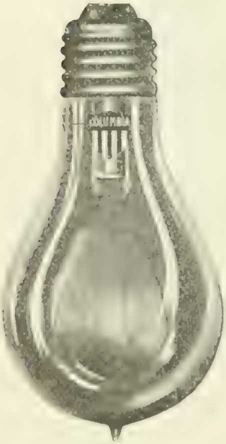


Figure 4—Carbon Lamp

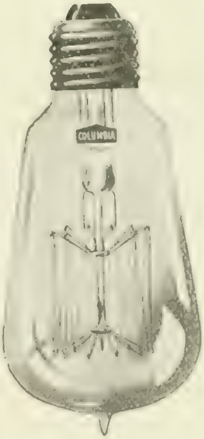


Figure 5—Tantalum Lamp

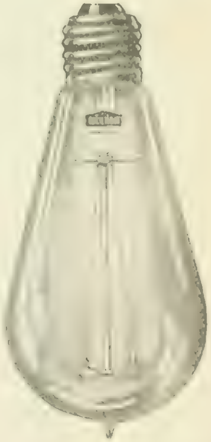


Figure 6—Tungsten Lamp

drop cords is not so serious in the case of the other two types of lamps. All of these types may be obtained in a number of different candle powers or *watts* capacity. A watt is the electrical unit of power and is equal to the number of volts multiplied by the number of amperes. One horse-power equals 746 watts. Thus there are tungsten lamps for 110-volt service of 25, 40, 60 watts capacity and even higher, while the tantalum lamp may be regularly obtained in the 25, 40, 50, and 80-watt sizes.

The approximate currents used by 110-volt lamps are as follows:

CARBON	TANTALUM	TUNGSTEN
4 c-p, 17.5 watts-0.16 amp	12.5 c-p, 25 watts -0.23 amp	20 c-p, 25 watts—0.23 amp
8 c-p, 35.0 watts-0.32 amp	20 c-p, 40 watts--0.36 amp	32 c-p, 40 watts--0.36 amp

It will be noticed that the 25 and 40-watt tungstens give more light than the corresponding 25 and 40-watt tantalum lamps. These lamps in many instances have the bottom of the bowl frosted to avoid the direct glare downwards. Figs. 4, 5, and 6 give an idea of the appearance of the three lamps.

Too much attention cannot be paid to the choice of reflectors. They should be obtained for the purposes wanted. The day is past when shades or reflectors are mounted merely for appearance. For example, a reflector for reading purposes should throw the light downward; a light for the more general illumination of a room should have a shade that spreads the light more, though still in a generally downward direction; while for the illumination of large areas one which offers a wide diffusion of light should be employed. But an opaque reflector, even though it properly answers one of the above requirements, causes dark shadows around the ceiling, which, with the illuminated area below, produce a contrast that is disagreeable to the eyes. Thus a form of reflector that allows some light to be thrown on the ceiling is to be preferred.

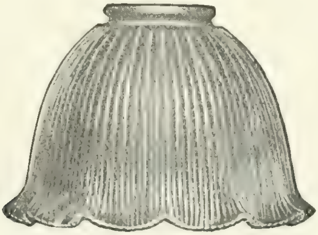
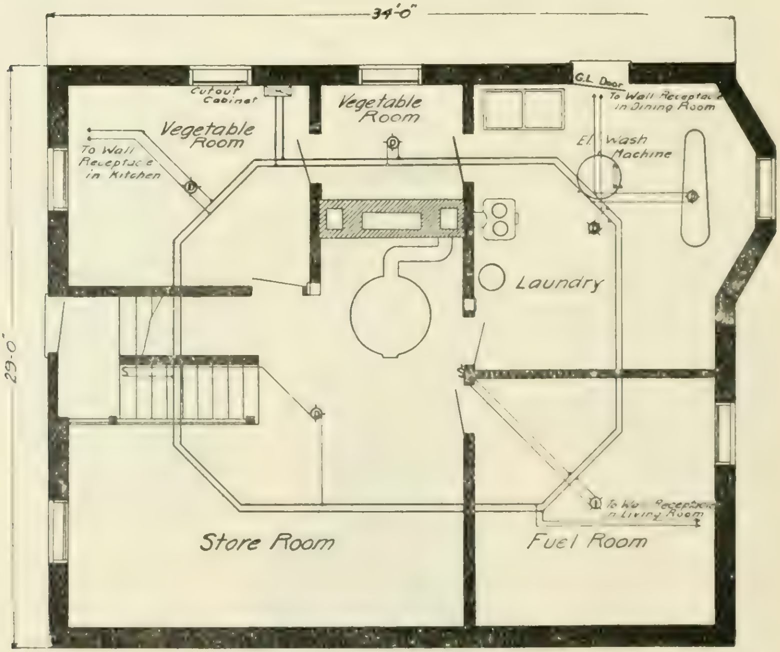


Fig. 7

There are now on the market clear glass reflectors with corrugations or prisms covering the surfaces, such for example as the Holophane type, which, due to these corrugations, may throw the light in any of the above three ways and still allow some of the light to reach the ceiling. They are known as the "focusing," "intensive," and "extensive" reflectors. Figure 7 represents a type.

It is a mistake to suppose that the distinctness of vision increases with the brightness of the light. Within certain limits the eye accommodates itself to different intensities of illumination by the contraction of the pupil when the light is too strong and by distension when it is not so intense. It is very desirable to avoid the direct glare of the strong light, otherwise, it will be difficult to see beyond, due to the contraction of the pupil caused by this glare. Under these conditions one



BASEMENT WIRING PLAN
Drop Cord Ceiling Outlet S Switch
Fig.—8

is "blinded", so to speak; so it is better to have a light hung away from the direct line of vision. By the use of lamps frosted at the bottom and by the correct choice of clear glass prismatic reflectors which prevent the glare from the sides, a satisfactory illumination with but a moderate amount of candle-power may be secured.

There is a considerable range in choice of fixtures. Figure 18 represents a 2-light brass fixture of moderate price, having a square outline which offers a simple though effective decorative effect. Cheaper fixtures which will serve the purpose equally well, are on the market, but in any event only those fixtures should be chosen for tungsten lights which will permit them to hang vertically.

Figures 8, 9, 10, represent plans of the basement, first, and second floors of a house. Let us consider the needs of this house in the way of lighting.

Basement. Inspecting Fig. 8, the basement plan, we find it subdivided into a laundry, fuel room, vegetable rooms, an alcove for the furnace, and a large open space for general storage and other purposes. On the whole, lights will be on for but a short time in the basement, so that cheap 8 candle-power carbon lamps may be used, with the possible exception of those in the laundry if night work is planned. Such will not be assumed to be the case here, however. Neither will it be necessary to install shades since the principle object of the basement illumination is to enable one to find his way about. Simple drop cords issuing from porcelain ceiling rosettes, and fitted with ordinary key sockets are considered sufficient for most of the lights. This combination is illustrated by Fig. 11. In the fuel room the lamp should be screwed directly into a porcelain ceiling receptacle, Fig. 12, in order to be out of the way of the coal. A snap switch, Fig. 13, controlling this light, should be placed near the door of the fuel room. The coal pile prevents the use of an ordinary key socket. A switch should also be placed at the upper landing of the cellar steps to control a lamp which lights the way down the steps. This may as well be the one near the furnace. From here on the other lights may be turned on and off progressively by employing ordinary key sockets. The landing switch avoids the necessity of groping one's way down the steps and then feeling the way to a lamp. The drop cords should be adjusted to allow the lamps to hang about six and one half feet from the floor.

First Floor. On the first floor special attention should be paid to the lighting features. The kitchen should have two lights, one suspended near the range and another adjustable bracket light, Fig. 17, between the sink and the kitchen table. The first may be hung from a drop cord about six and one-half feet from the floor. A 25-watt, 110 volt, tungsten lamp with frosted tip, supplied with a keyless socket and an intensive clear glass prismatic reflector may be used. A switch controlling this light should be placed near the door leading to the side hall. The bracket light may be supplied with a 40-watt frosted tantalum lamp with key socket. A bell shaped reflector with frosted tip lamp might be used here but is scarcely necessary. The tantalum lamp is preferable because of the danger of rupturing the filament of a tungsten lamp by the inevitable jar when swinging the bracket from one side to the other, or when turning the key on or off. Thus the drop light would serve as a general illuminant as well as a light for the range, while the bracket fixture would direct the light either to the sink or to the kitchen table.

The pantry should be supplied with a porcelain ceiling receptacle, a 25-watt frosted tip tungsten lamp, and a shallow opal reflector.

The dining room should be furnished with a two-light fixture, Fig. 18, hung about six feet from the floor and directly over the dining table. It should be supplied with two 25-watt tungsten lamps, keyless sockets, and two intensive type reflectors. This spreads the light evenly over the table and also offers some general illumination. A switch controlling these lights should be placed near the pantry door for convenience of access from the kitchen.

The living room is where the family usually gathers in the evening, and so should be inviting and cheerful. This room also should have a two-light fixture hung about six and one half feet from the floor and directly over the library table. The fixture is supplied with two key sockets, one intensive and one focusing type of reflector, a 40-watt frosted tip tungsten lamp

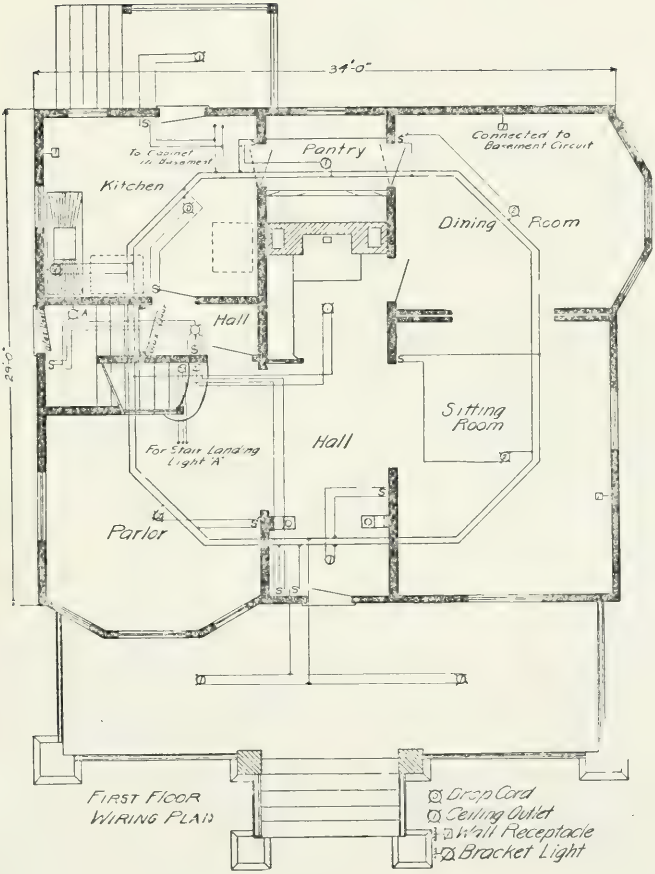

34'-0"
29'-0"
Connected to Basement Circuit
Pantry
To Cabinet in Basement
Kitchen
Dining Room
Hall
A
Sitting Room
Hall
For Stair Landing Light 'A'
Parlor
S
First Floor Wiring Plan
Drop Cord
Ceiling Outlet
Wall Receptacle
Bracket Light

Fig. 9

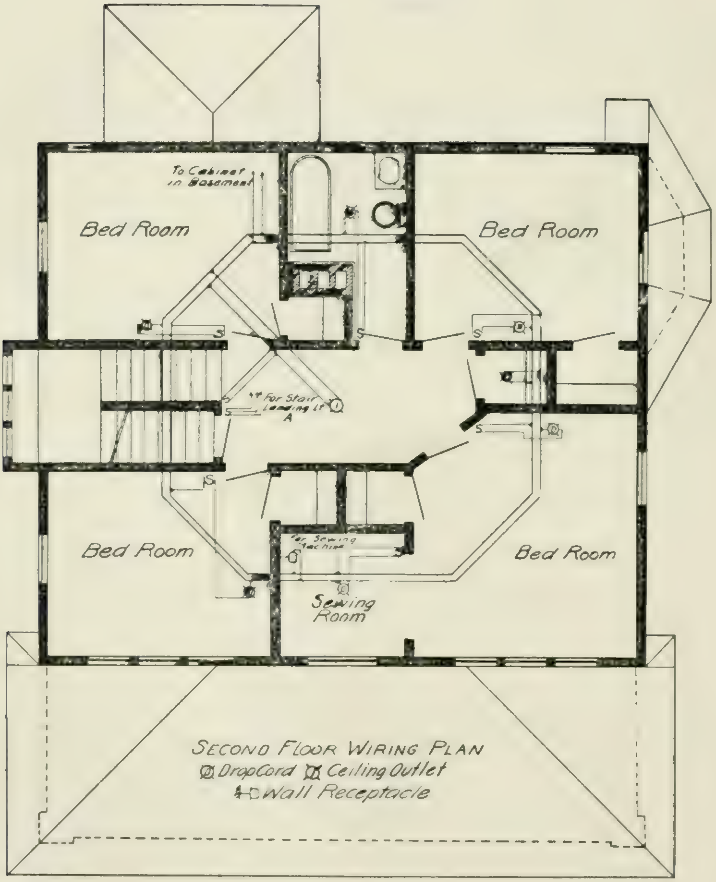

To Cabinet in Basement
Bed Room
Bed Room
S
S
S
"A" For Stair Landing Lt A
S
S
S
S
Bed Room
For Sewing Machine
Sewing Room
Bed Room
SECOND FLOOR WIRING PLAN
Drop Cord
Ceiling Outlet
Wall Receptacle

Fig. 10

under the intensive reflector and a 25-watt frosted tip tungsten lamp under the focusing shade. The 40-watt lamp with its shade will provide a good general illumination, while the other throwing the light directly downward may be used for reading purposes. A switch near the hall entrance controls this fixture, but key sockets are provided for economy in lamp operation. At certain times but one lamp is needed. Fortunately the two styles of reflectors differ so little in appearance, that such difference passes unnoticed.

A 25-watt, clear bulb lamp, encased in a prismatic ball globe may be hung in front of the fire-place and about six and one half feet from the floor. The fixture may be of a design similar to that shown by Fig. 18, or the lamp and ball may be suspended by a heavy chain.

The parlor should have a two-light fixture matching those in the dining and sitting rooms, and be provided with two key sockets, two frosted tip 25-watt tungsten lamps, and two intensive type reflectors. A switch should be placed near the hall opening to control this light.

A 4 candle power carbon lamp screwed into a porcelain ceiling receptacle such as is illustrated by Fig. 12, should be placed in the small side hall. It should be controlled by two switches, one near the outside door below and the other near the parlor entrance. The same thing is true of the hall light near the fireplace. Entering by either outside door one may light the way up stairs and put out the lights behind him. A switch at the front door lights the hall lamp; another switch near the foot of the stairs puts it out. A switch near the foot of the stairs lights the landing lamp, and a switch near the second floor landing puts it out. Any of the switches used for putting out a light also may be used to light it, so that one may light the way from the second floor to the front door and turn off the lamps behind him. The external appearance of the common switch controlling a light at one point only and the special switches for controlling at two places, is very much the same; but whereas the former switch has but two wires connected to it, the latter must have three. Figure 21a illustrates the wiring diagram of a lamp controlled from two points.

The vestibule should have a ceiling fixture similar to that re-

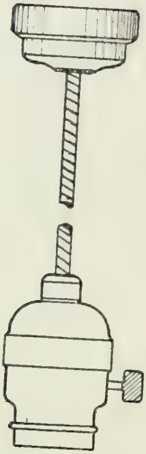


Fig. 11

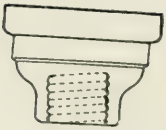


Fig.12

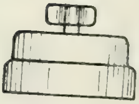


Fig. 13

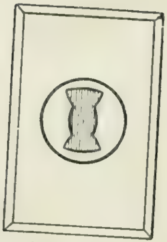


Fig. 14

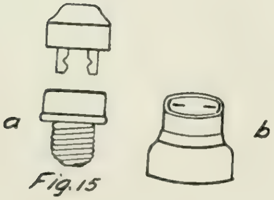


Fig.15

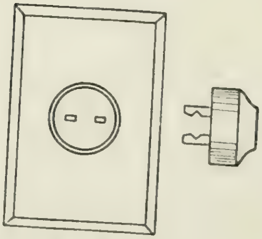


Fig. 16

presented by Fig. 19 excepting that the encasing globe is replaced by an intensive prismatic reflector, and the lamp is a 25-watt frosted tip tungsten lamp.

The front porch should be equipped with two ceiling fixtures of the type shown in Fig. 19. Twenty-five watt clear tungsten lamps should be used, equipped with either frosted or opalescent globes.

An 8 candle-power carbon lamp screwed into a porcelain ceiling receptacle will be sufficient for the rear porch.

Second Floor. All the lamps on the second floor including the landing light should be 25-watt tungstens excepting that in the hall closet which should be a 4-candle power carbon lamp. The landing light should have a short bracket fixture, Fig. 20, in keeping with the design of the fixtures on the first floor. Since its purpose is to afford light on the stairs, an unfrosted lamp incased in a prismatic clear glass ball for general illumination may be used. The upper hall may have a ceiling fixture similar to those on the front porch. The bedrooms should have drop cord lights hung over the dressers, about seven feet from the floor. They should have frosted tips and be supplied with keyless sockets and shallow opal shades with scalloped edges. A better plan would be to add another light to each bedroom, suspended from the center of the ceiling for the purpose of general illumination. But the expense of this addition is an important item and is not considered warranted where economy is a leading factor, and especially since a bedroom light is generally not used for long periods of time. By the use of a shallow shade some of the light from the lamp over the dresser is thrown into the room and at the same time enough light is given in the direction most needed. The bath room will be lighted sufficiently by a 25-watt frosted tip lamp and scalloped opal shade, hung about seven feet from the floor.

Care should be exercised to make the cord of the hall closet lamp short, so as to prevent any danger of contact with the contents of the closet. A lamp is a generator of heat and if this heat is confined, as for example when the lamp is closely surrounded by a mass of linen, it may start a fire. The second

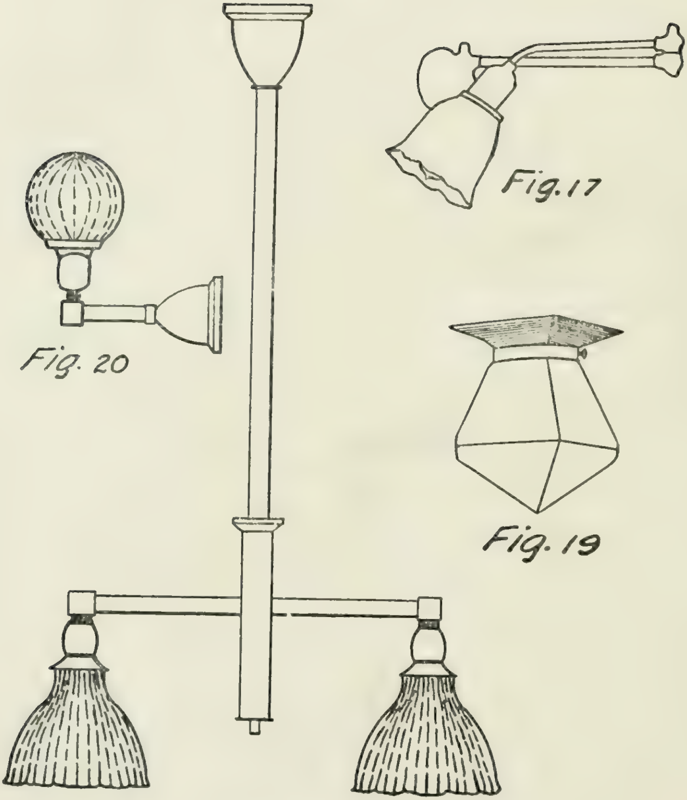


Fig. 17

Fig. 20

Fig. 19

Fig. 18

floor drop cords can be replaced by fixtures if a more expensive outlay is not objectionable.

Receptacles. In addition to the lighting outlets, four wall receptacles may be provided in the house primarily for small motor circuits. There should be one each in the kitchen, dining room, and sitting room, which may be utilized for a fan motor. Then there should be an outlet in the sewing room for a sewing-machine motor. Of course, these receptacles may also serve for connections to portable table lamp, vacuum cleaner, or any other electric household utensil or appliance. The wall receptacles on the first floor are preferably connected to the basement circuit, which should be especially wired with a larger size of copper wire to accommodate the possible future increase of load in addition to the lamps. It is better to install this larger sized wire when wiring the house because the additional cost is so small. The basement circuit should be considered more in the nature of a "power" circuit than one for lighting, and should be connected up to the source of power under rules governing motor circuits rather than those of lighting circuits. Two outlets should be provided for in the laundry. One may be of the ordinary drop cord type intended principally for the lamp but may be used during the day for the washing machine motor which takes but little power. The other

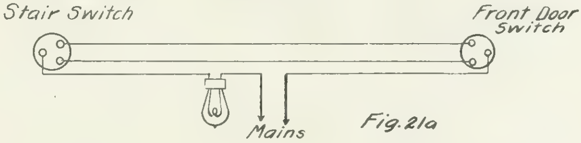


Fig. 21a

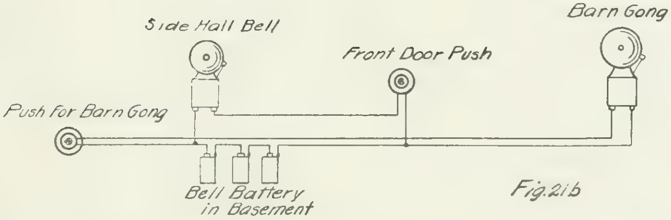


Fig. 21b

outlet is like the first excepting that the drop cord should be of larger sized copper to accommodate the heavier current taken by the flat iron. Of course another lamp may be used here when desired.

Switches and Plug Receptacles. Figure 13 represents an inexpensive snap switch with porcelain base. Figure 14 illustrates a more expensive flush type which may be obtained in a finish to match the other fixtures. The degree of economy is the deciding factor in the choice. Figures 15b and 16 represent styles of plug receptacles used for wall outlets. The former is of porcelain and the latter, more expensive, is of a finish to match the fixtures. Figure 15a shows an Edison plug receptacle which may be screwed into a socket in place of a lamp, thus permitting a small motor or other appliance to be connected at the regular lighting outlets. This may be taken advantage of in the laundry where only drop cords are used.

THE BARN INSTALLATION

Ordinarily the barn is not supplied with artificial illumination, but a safe form of lighting is a great convenience especially during the winter months when the sun rises late and sets early. Electric lamps are ideal for barn illumination, and fortunately but few are needed in order to find one's way about. The system of wiring is very simple. Twenty-five watt tungsten lamps may be used throughout and should be mounted directly on the ceiling joists, or, where necessary, drop cords may be used to bring the lights down to about 10 feet from the floor. They should be supplied with flat tin reflectors, white enameled inside.

Figures 22 and 23 are respectively the reproductions, with very little alteration, of the published ground floor and first floor plans of a barn actually constructed. They are not inserted here for the purpose of illustrating excellence in barn arrangement, but rather to show a lighting and wiring plan which can be modified to suit individual needs. It is to be remembered that the lights about a barn are purposely few in number, the object being merely to find one's way about. The

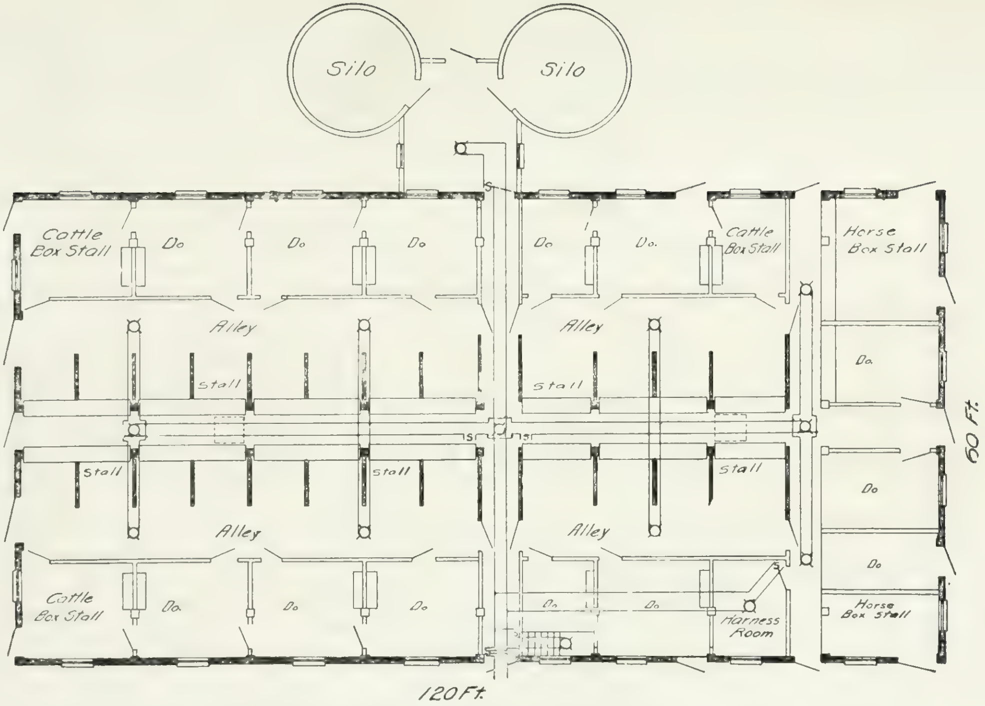


Fig.—22. Wiring Plan for Ground Floor of Barn

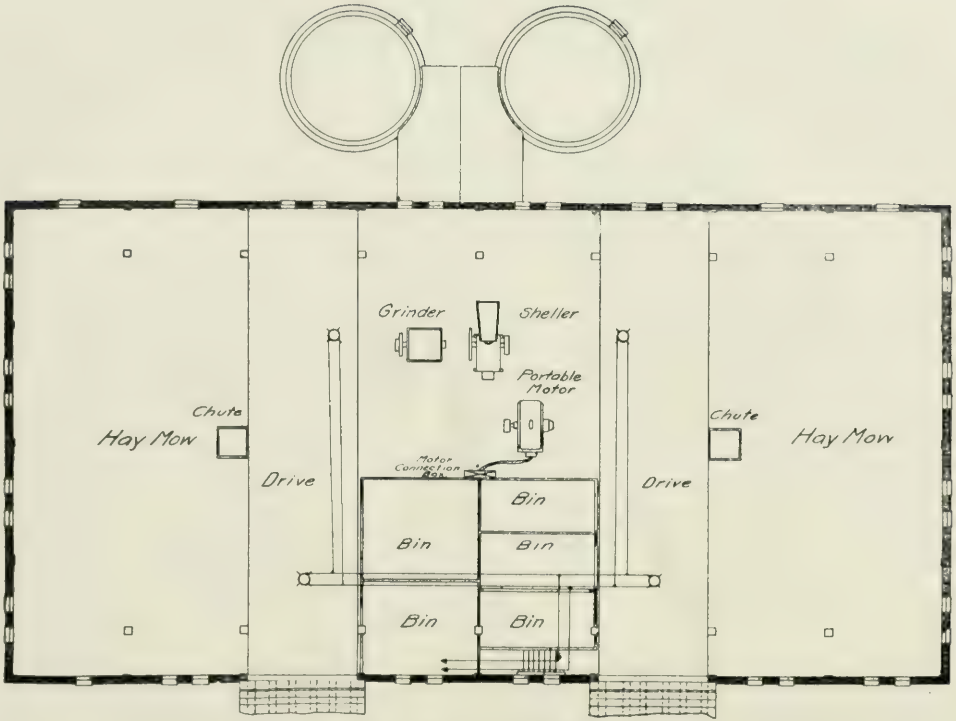


Fig. 23—Wiring Plan for First Floor of Barn

lighting would be considered poor if based on the standards set for house illumination.

Ground Floor. Fig. 22 illustrates the lighting and wiring plan for this floor. The door opposite the silo entry is considered the usual entrance to the barn. A main snap switch nearby connects the entire barn lighting system with power. Opening this switch insures that all lights are off on leaving the premises. At the very center of the barn at the crossing of the alleys is a lamp without individual switch control, so that as soon as the main switch is closed it lights up, thus allowing one to reach any of the other switches without groping. The other lamps are grouped with a view to lighting sections as needed. For example, as the needs of the horses and cattle in the right half of the barn are attended to, this group of lights may be turned off and the lights for the left half of the barn turned on. Lights with switches are also provided for the harness room, stairs, and the room connecting the barn with the silos.

First Floor. Inspecting Fig. 23, it is noticed that half the space on this floor is taken up by the hay mows. Part of the middle space is taken up by grain bins. Four lamps are considered sufficient for the needs of this part of the barn. Two are hung over each driveway about nine feet from the floor in front of the bins. The other two farther back are about ten feet from the floor, and serve for general lighting. These lamps are all controlled by one switch.

The Motor Circuit. The central space of the first floor directly behind the bins is utilized for the corn sheller, shredder, grinder, etc., to any of which a portable motor may be belted. A special motor circuit of heavy wire should be run to a convenient connection box which may be reached by a flexible cable from the motor. If desired an additional connection box may be placed out doors, in which event the mains are tapped at some convenient spot and service wires run where desired. Such a connection box is easily made and a convenient form is illustrated by Fig. 24.

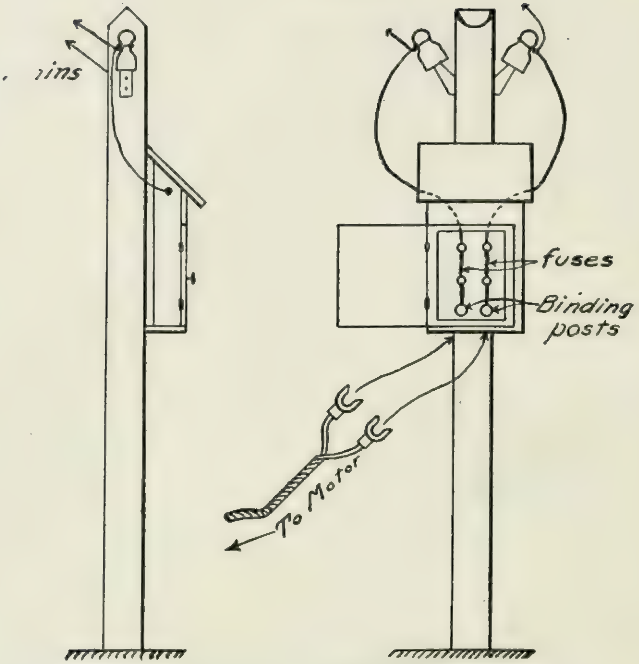


Fig. 24—Connection Box for Power Motor

INSTALLATION REQUIREMENTS

Glancing through the preceding pages it is seen that the following appliances are to be supplied with electric power:

Lamps in house, barn, generating room, repair shop, and creamery.

Fan motor.

Washing-machine motor.

Electric flat-iron.

Sewing-machine motor.

One horse-power motor for pump.

Six horse-power portable motor.

The 6 horse-power motor is chosen on account of the fact that no piece of machinery in this installation for which electric power is to be provided, is assumed to take more than 6 horse-power to operate it.

THE POWER PLANT

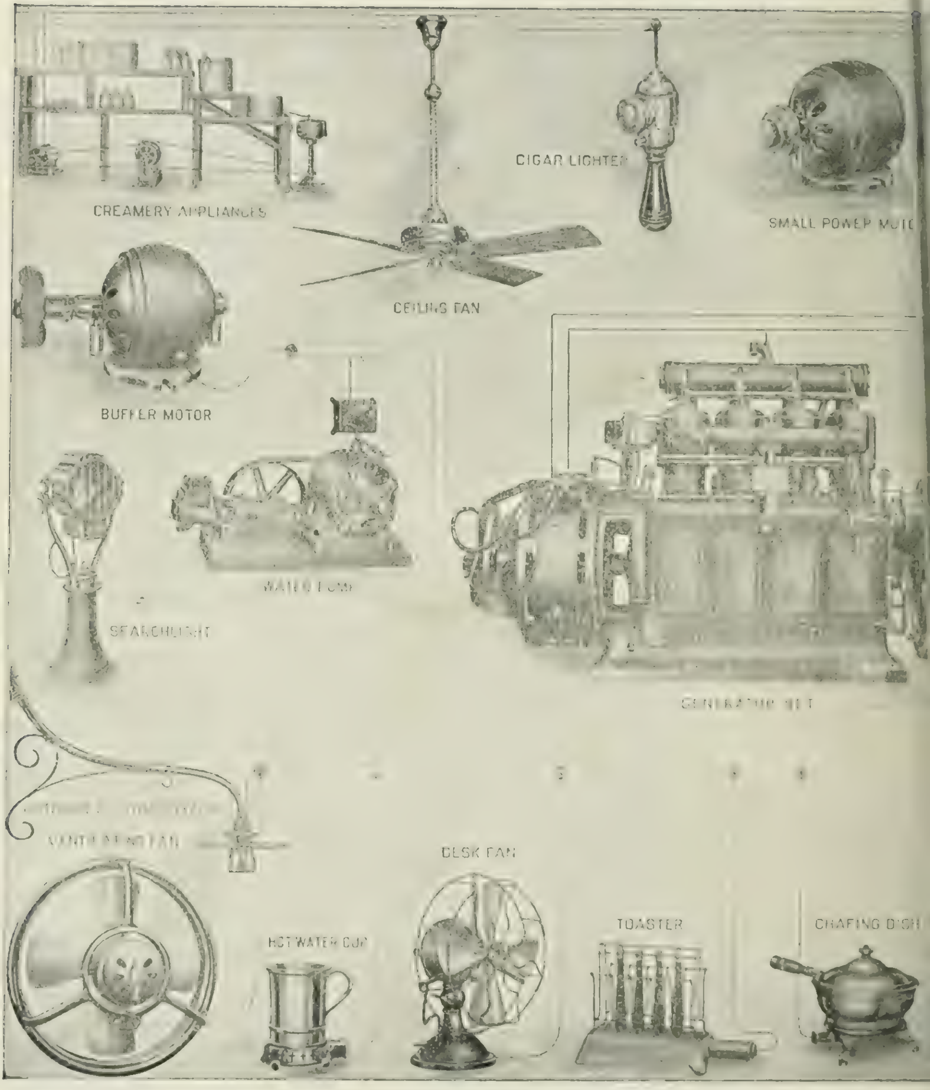
In order to determine the size of storage battery and of generating plant, it is first necessary to determine the duty required of each and then select the capacity in accordance with such duty.

Storage Battery. To keep down the expense of the battery installation, only the lamps and small house motors will be considered as using storage battery power. All larger needs for electric power will be obtained directly from the generator. The voltage of one cell of the battery varies from about 2.2 volts when fully charged, to 1.8 volts when discharged to the safe limit. Therefore since the lamps are for 110 volts, 56 cells are needed for the purpose. This will give more than 110 volts at the beginning of the discharge, and a little lower towards the end. As it happens the conditions of demand are approximately such that when the freshly charged cells are used, the demand for current is the greatest and towards the end of discharge it is less. Hence the battery voltage is highest when it should be, namely, when the current is heavy causing more voltage to be lost in the battery and in the resistance of the wires to the house. So the lamp brightness is less affected by this changing battery voltage than might be supposed. A cell is rated by its "ampere-hour" capacity, that is, by the number of hours it takes to discharge from 2.2 volts to 1.8 volts, multiplied by the amperes flowing during this time. For example, if it takes 8 hours to discharge a cell at a 5-ampere rate, the capacity of this cell is said to be 40 ampere-hours. This cell would also discharge 8 amperes for nearly 5 hours. But the 8-hour basis is considered the normal one. In other words, the current drawn from a storage battery should not ordinarily exceed that which would discharge the battery in eight hours.

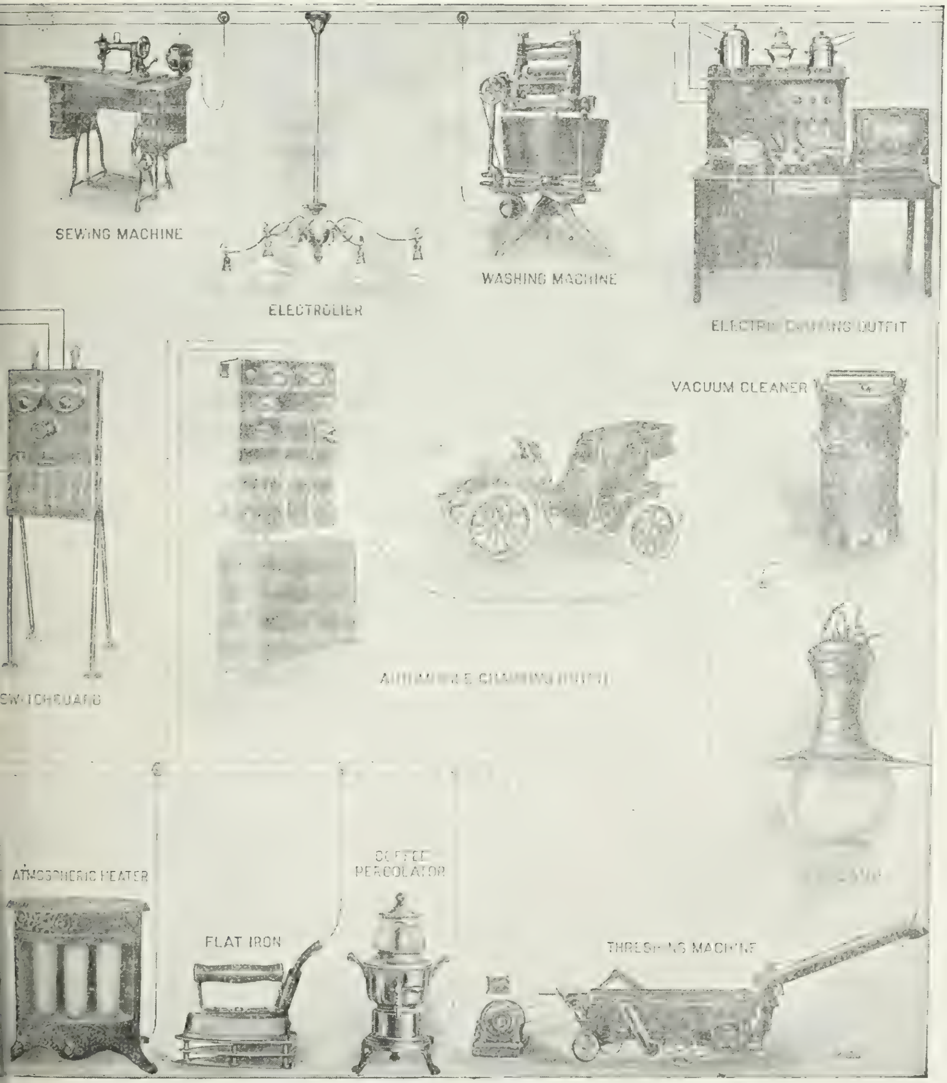
A lamp which takes half an ampere of current and burns an hour and a half is said to consume 1½x½, which equals ¾ of an ampere-hour.. This must not be confused with the "watts" power consumption.

The lighting schedule on page 31 illustrates the method of securing the ampere-hour battery capacity required for the lights alone and may be used as a basis for any other installation. Winter conditions have been assumed because the maximum demand occurs at that season.

The lights in the engine room are supposed to be used only



Illustrations Showing the Various Us



Vhich Electric Power May be Applied.

LIGHTING SCHEDULE

Place	No. Lights Used	Kind	When Used	Total Hours in Use	Amperes per Lamp	Total Amperes per Place	Ampere-hr.
Kitchen	1	25—watt Tungsten	Morn. Eve.	4	0.23	0.23	0.92
Kitchen	1	40—watt Tantalum	Morn. Eve.	4	0.36	0.36	1.44
Pantry	1	25—watt Tungsten	Morn. Eve.	4	0.23	0.23	0.92
Dining Room	2	25—watt Tungsten	Morn. Eve.	3	0.23	0.46	1.38
[illegible] Room	1	40—watt Tungsten	Eve. Only	2	0.36	0.36	0.72
Living Room	1	25—watt Tungsten	Eve. Only	2	0.23	0.23	0.46
Parlor	2	25—watt Tungsten	Eve. Only	1	0.23	0.46	0.46
Side Hall	1	4 c. p. Carbon	Morn. Eve.	3	0.16	0.16	0.48
Fire Place	1	25—watt Tungsten	Eve. Only	2	0.23	0.23	0.46
Vestibule	1	25—watt Tungsten	Eve.	Small			
Front Porch	2	25—watt Tungsten	Eve. Only	2	0.23	0.46	0.92
Rear Porch	1	8 c. p. Carbon	Morn. Eve.	2	0.25	0.25	0.50
Landing	1	25—watt Tungsten	Morn. Eve.	2	0.23	0.23	0.46
2nd Floor Hall	1	25—watt Tungsten	Morn. Eve.	1½	0.23	0.23	0.35
Bed Rooms	5	25—watt Tungsten	Morn. Eve.	1	0.23	1.15	1.15
Bath	1	25—watt Tungsten	Morn. Eve.	1	0.23		0.23
Hall Closet	1	4 c. p. Carbon	Day Time	Small			
Basement	2	8 c. p. Carbon	Morn. Eve.	1	0.25	0.50	0.50
	Total Ampere-hours for house						11.35
Barn, Ground Floor	11	25—watt Tungsten	Morn. Eve.	4	0.23	2.53	10.12
Harness Room	1	25—watt Tungsten	Morn. Eve.	1	0.23	0.23	0.23
Silo Entry	1	25—watt Tungsten	Morn. Eve.	1	0.23	0.23	0.23
Barn 1st Floor	4	25—watt Tungsten	Morn. Eve.	1½	0.23	0.92	1.38
Stairs Barn	1	25—watt Tungsten	Morn. Eve.	1½	0.23	0.23	0.35
	Total Ampere-hours for barn						12.31

when the generator is running and so need not be considered in the battery calculations. It is also assumed that the power for the lights in the shop and dairy is so infrequently required that no extra capacity in storage battery is necessary for this purpose. Since the line shaft is usually running when these rooms are used the power for lights, when needed, may come directly from the generator. Should conditions in individual cases be such as to demand appreciable power from the battery for these rooms, extra capacity as calculated by the above method, should be provided.

It is seen from this schedule that it requires between 23 and 24 ampere-hours of storage battery capacity to light house and barn properly. In addition there is to be considered the ampere-hour consumption of the small motors as follows:

Sewing-machine motor, taking about ½ ampere, running (say) 3 hrs. when used—1.5 amp. hrs.

Washing-machine motor, taking about 1.3 amperes, running (say) 3 hrs. when used—4.0 amp. hrs.

Fan motor, taking about 0.4 ampere, running (say) 10 hours when used—4.0 amp. hrs.

The fan motor, however, is used only during the summer months when the number of ampere-hours required for lighting is considerably reduced, so that it need not be considered. The iron should be used only when the generator is running, so as to reduce the required battery capacity. The power required for the iron is considerable. The sewing-machine and washing-machine motors also might be planned for in this way, but they consume so little power that to make them available at any time, they are included in the estimate for battery capacity.

This makes a final total of about 29 ampere-hours to be provided for. The nearest battery capacity suitable for this installation and listed by manufacturers' catalogs is either a 24 ampere-hour battery (3 amp. normal discharge rate) or a 36 ampere-hour battery (4½ amps. normal discharge rate). The cost of each complete, consisting of 56 elements, 57 glass jars, 14 bolt connectors, 6 wood sand trays, hydrometer, 48 insulators, and necessary electrolyte, is about $200.00 and $260.00

respectively. The battery of larger capacity is chosen, because the first is too small and there would be some danger of unsatisfactory service, while the larger one has ample reserve capacity for exceptional current demands. In fact a vacuum cleaner, if desired, may be supplied by this battery. It also permits of some future extension in illumination.

The Generating Plant. Since the 6 horse-power motor represents the maximum demand on the generator, the capacity of the latter is determined by this motor. Generators are rated in "kilowatts." A kilowatt is about 1 1-3 horse-power. Therefore, allowing one third of the power output of the generator for the losses in the motor and mains, we find that an 8 horsepower, or about a 6 kilowatt, generator will be fully loaded when the motor is working at its full capacity. The generator chosen should, therefore, be of this capacity. Allowing for belt loss and the losses in the generator, a gasoline engine delivering 10 horse-power would be required.

It is necessary that the generator run at a more constant speed than is maintained by the ordinary gasoline engine. Engines are now built especially for this class of service with extra heavy flywheels, and sensitive governors.

Switchboard. The switchboard should be provided with the following equipment:

A main switch for controlling the generator.

Switches for controlling the battery with or without supplying outside power at the same time.

Switches to enable the generator to supply all the power on the line with storage battery cut out.

Switches to enable the battery to supply the power with generator cut out.

Ammeters for reading the charging or discharging current and the current load on the generator.

A voltmeter for reading the several voltages.

A circuit-breaker for opening the circuit on overloads, or in case the current reverses through the battery.

Rheostat for raising or lowering the generator voltage.

Figure 25a gives an idea of the appearance of the front of

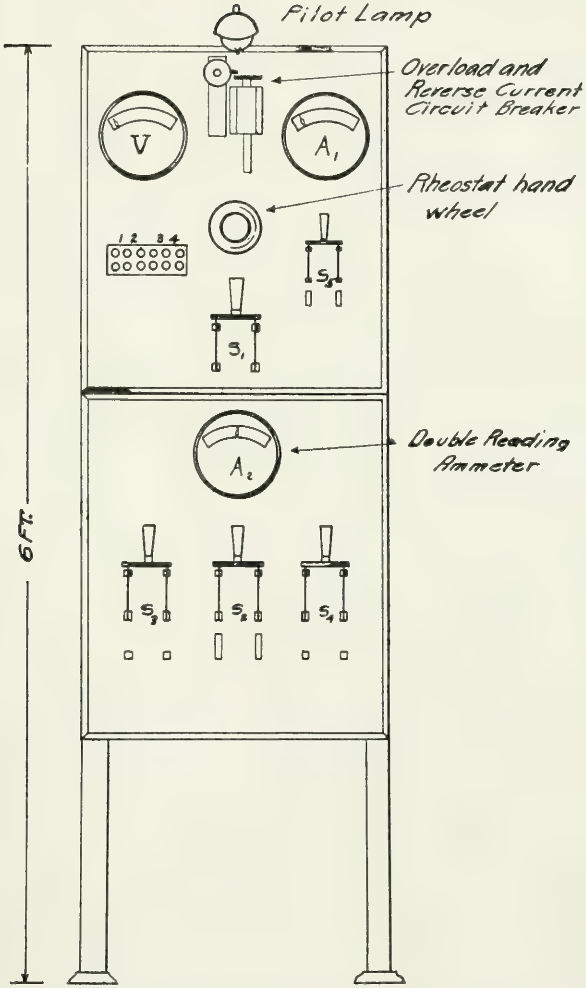


Fig. 25 a—Switchboard for Lighting Plant on Farm such a board and Fig. 25b of the diagram of connections. In the latter no attempt is made to place the instruments and switches in any particular order, but the lettering on one figure corresponds to that on the other. The heavy lines in Fig. 25b indicate the circuits carrying considerable currents. The finer lines represent connections carrying but small currents. The board is supplied with an ammeter (A_1) to read the current load on the generator, an ammeter (A_2) with the "zero" in the middle of the scale to indicate the charging or discharging current of the battery, and a voltmeter to read the several voltages by means of the 12-hole plug receptacle.

There is also a generator switch (S_1), a service switch (S_2) to control the outgoing power, double-throw switches (S_3) and (S_4) for battery control, a small switch (S_5) for the local lights, and an overload and reverse current circuit-breaker, to protect generator from overloads and to prevent battery from reversing the current through the generator.

Engine Room. Though the writer is aware that a separate building for the generating plant is not always feasible, especially when the necessity for strict economy is a deciding factor, yet, since he cannot hope to include all the particular conditions as found on different farms, he assumes what seems to be a good plan,--to separate the dairy and engine rooms from the barn proper and house them in a separate building, which may also conveniently include the repair shop. This permits of the convenient use of the line shaft referred to in the preceding pages. Figure 26 shows a plan embodying this arrangement. The lights in the engine room may be 8 candle-power carbon lamps supplied with key sockets hung from drop-cords, near the points where light is most desired, namely, near the engine, generator, and battery. The other rooms should have wall switches and 25-watt tungsten lamps. Ample space in the engine room should be provided. Crowding should be particularly avoided. A room with numerous windows is preferable to one with few. The gasoline supply tank should be buried outside to decrease fire risk. Running water is desirable for cylinder cooling purposes and if there is an ample supply it is

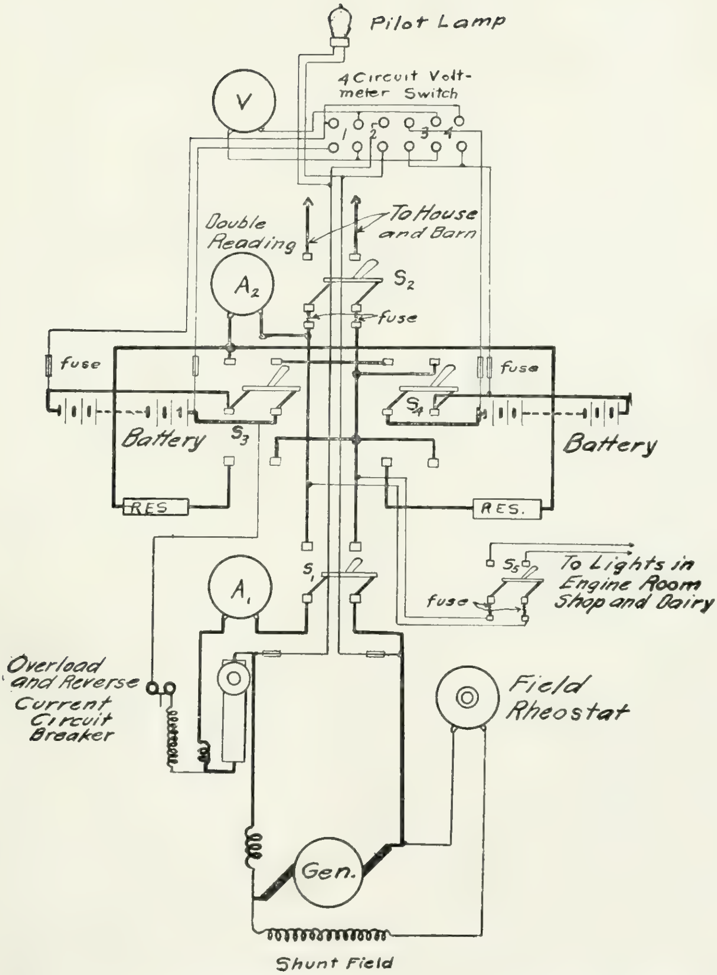


Fig. 25b—Wiring Diagram of Switchboard for Lighting Plant on Farm

recommended. Otherwise, the cooling tank will serve. The engine should be bolted to a heavy concrete foundation. This is not essential in the case of the generator.

It may be found that space in the barn or other out buildings may be utilized in carrying out the plans, in which case the expense of a separate structure is saved.

ESTIMATES

The following estimates are based on the prices at hand at the time of writing. No statement can be made as to the absolute accuracy of such figures, because of changing market prices and the fact that manufacturers themselves differ in their prices for similar products. But it is believed that those given here are not far from correct. It is hoped that they may serve as a guide for estimating particular installations.

POWER PLANT.

10 h. p. gasoline engine, complete with cooling and fuel tank, igniter, etc	$ 420.00
Material for engine foundation	4.00
6 kw., 125-volt, direct current, compound wound generator	175.00
Belt	19.00
Switchboard complete with instruments, resistances, etc.	120.00
Wire and conduit, connecting generator and battery to switchboard	9.00
58-cell storage battery, complete with accessories	260.00
Battery rack (home made)	10.00
	$1017.00

MATERIAL FOR POWER HOUSE.

150 feet No. 14, rubber covered copper wire, at $11.00 per 1000 feet	$ 1.65
2 key sockets at 0.20	.40
3 keyless sockets at 0.18	.54
2 ceiling rosettes at 0.15	.30

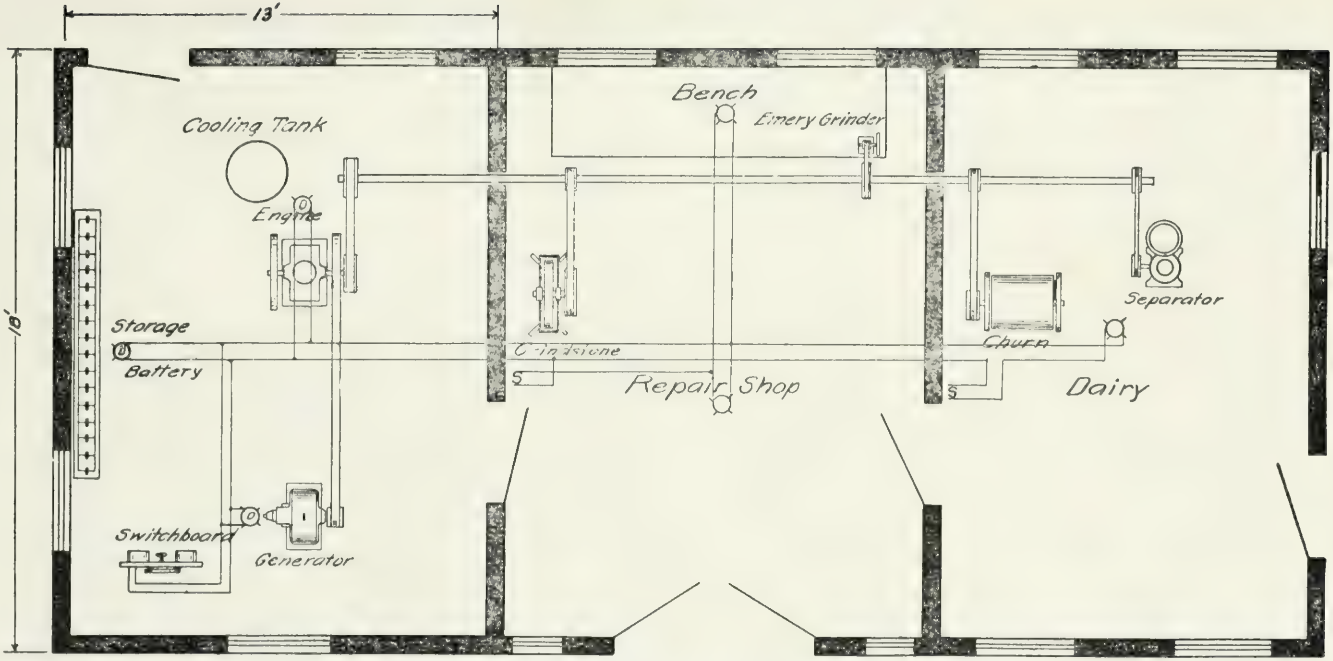


Fig. 26—Arrangement of Power Room, Repair Shop, and Dairy

3 ceiling sockets at 0.25	.75
3 flat enamelled steel shades and holders at 0.15	.45
Two 8 candle-power, 110-volt, carbon lamps at 0.20	.40
10 ft. No. 18 lamp cord	.13
3 25-watt, 110-volt, tungsten lamps at 0.90	2.70
2 single-pole snap switches at 0.20	.40
Porcelain cleats	.25
	$7.97

DWELLING.

150 ft. No. 12, rubber covered wire at $14.50 per 1000 ft.	$ 2.20
1100 ft. No. 14, rubber covered wire at $11.00 per 1000 ft	12.10
25 ft. lamp cord	.33
Porcelain tubes and cleats	3.00
13 sockets for drop cord (Fig. 11)	2.45
3 porcelain ceiling receptacles (Fig. 12) at .25	.75
1 keyless ceiling socket	.25
13 porcelain ceiling rosettes for lamp cords (Fig. 11 top) at .15	1.95
1 attachment plug for socket (Fig. 15a)	.25
4 wall attachment plugs (porcelain, Fig. 15b) at .25	1.00
17 single-pole snap switches (Fig. 13) at .20	3.40
6 three-point snap switches (Fig. 13) at .40	2.40
3 2-light pendant fixtures with sockets and shades (Fig. 18)	24.00
1 bracket light with socket and Holophane ball (Fig. 20)	2.60
1 adjustable bracket with socket (Fig. 17)	1.00
1 1-light pendant fixture, with socket and ball (front hall)	4.00
3 ceiling fixtures with square stalactite shades (Fig. 19) at $2.25	6.75
1 ceiling fixture with Holophane shade (vestibule)	2.25
7 shallow crimped opal shades at .18	1.26
7 8-c. p. 110-volt, carbon lamps at .20	1.40
2 4-c. p., 110-volt, carbon lamps at .20	.40
1 40-watt, 110-volt, tungsten lamp	1.00
1 40-watt, 110-volt frosted tantalum lamp	.60
18 25-watt, 110-volt tungsten lamps at .90	16.20
1 panelette with main switch (for cut-out cabinet)	1.35
	$92.89

BARN.

800 ft. No. 14 rubber covered wire at $11.00 per 1000 ft.	$ 8.80
14 keyless ceiling sockets at .25	3.50
4 porcelain ceiling rosettes at .15	.60
4 keyless sockets at .18	.72
1 double-pole snap switch	.40
6 single-pole, snap switches at .20	1.20
18 flat enamelled steel shades and holders at .15	2.70
25 ft. lamp cord	.33
Porcelain cleats, insulators, etc.	2.50
18 25-watt, 110-volt tungsten lamps at .90	16.20
1 2-circuit panelette with main switch	.90
	$37.85
Six h. p., direct current, 110 volt, shunt motor, with starting box and switch	$165.00
Materials for connection box (iron box, lugs, etc.)	5.50
	$170.50

OUTSIDE.

400 ft. No. 6 weather proof copper wire (to barn and connection box)	$ 9.20
400 ft. No. 10 weather proof copper wire (to house)	4.80
	$14.00
2 25-foot poles with pins and insulators	$ 3.50
6 curved end tubes (Fig. 27a)	1.00
6 glass insulators and wood bracket pins	.30
1 connection box (wood, lugs, etc.)	2.50
One horse-power, 110-volt, direct current shunt motor	50.00
	$57.30

OTHER ITEMS.

Nails, screws, sheet asbestos, solder, tape, etc	$ 5.00
14 days labor (electrician at $3.50, helper at $2.50)	84.00
	$89.00
Total estimate for installation as described	$1486.50

3 *K. W. Installation.* It may be found that a 3-kilowatt plant will meet the requirements on some farms. The following are the estimates for a plant of this size. This plant will satisfactorily operate a 3 horse-power motor and the appliances as described above.

5 h. p. gasoline engine, complete with cooling and fuel tank, igniter, etc	$ 280.00
Material for engine foundation	3.00
3 kw. 125-volt, direct current, compound wound generator	125.00
Belt	7.00
Switchboard, complete with instruments, resistances, etc	120.00
Wire and conduit, connecting generator and battery to switchboard	6.00
56-cell storage battery complete with accessories	260.00
Battery rack	10.00
Material for power house	8.00
Material for dwelling	92.90
Material for barn	37.85
5 h. p., direct current, 110-volt, shunt motor, with starting box and switch	100.00
400 ft. No. 8 weather proof copper wire	6.25
400 ft. No. 10 weather proof copper wire	4.80
All other items for "Outside" as before	57.30
Nails, screws, sheet asbestos, etc	5.00
Labor	84.00
Total estimate	$1207.10

Lighting Only: House and Barn. There are three voltages that may be considered feasible for the lighting of country dwellings—110 volts, 60 volts, and 30 volts. Lamps are now manufactured regularly which are suitable for these pressures. Any one of these voltages may be used where practically no power service is required. The 30-volt system is being advocated to a considerable extent at present, the reasons offered being as follows:

(a) There is now considerable standard apparatus for 30-volt service, owing to the fact that 32 volts is the standard voltage for car lighting. It is now possible to obtain fans, flat-irons, washing machine motors, etc., adapted to this voltage.

(b) The number of cells of storage battery is reduced, thus taking up less room and giving less trouble.

(c) The low voltage lamp filament is shorter and, therefore, less liable to rupture.

The writer admits these points, but nevertheless feels that the chief consideration in determining the voltage of the installation is the cost. The 110-volt system offers the advantage of transmission with small loss as compared with the lower voltage and, of course, apparatus for the higher voltage has been standard for a long time. Again he finds from his own experience that the 25-watt, 110-volt tungsten lamp is not by any means as fragile as it is popularly supposed to be, and is a very satisfactory illuminant. Storage cells smaller than about 25 ampere-hour rating (3 amperes normal discharge) are not recommended for general lighting service, and the limit for the 110-volt system is reached when the demand requires a battery of less capacity than about 24 ampere hours, when a lower voltage system using larger cells becomes a necessity. But above this point it appears that the question of cost should be the chief consideration. This centers mostly in the cost of the battery and it may not always follow that the low voltage storage battery is cheaper than the higher voltage battery for equivalent service.

The 30-volt system will be considered in this discussion. In figuring battery capacity, it is only necessary to remember that the current which a lamp of given candle-power takes increases as the voltage rating decreases. For example, a 25-watt tungsten lamp at 110-volt rating takes about .23 ampere, or a little less than a quarter of an ampere. The same lamp at 25-volt rating (a little less than a quarter of 110) takes one ampere (a little more than four times .23). Thus, since we are dealing with a 30-volt system, the ampere hour capacity per cell is greater in the ratio of 110 to 30. On the other hand, the number of cells required to give an average of 30 volts is 16 as compared with 56 required for the 110-volt system. This means that sixteen 100 ampere-hour cells are needed. A 120 ampere-hour battery will cost about $200.00. This capacity will permit the use of the small house motors as before. The normal current for this battery is 15 amperes. Hence the generator must be capable of supplying at least this much for charging. The voltage of the generator should be about 45 volts in order to insure satisfactory charging of the 32-volt battery as contemplated. This battery is charged in one circuit whereas the 110-volt battery, first described, is charged in two circuits. This arrangement makes the cost of the switchboard somewhat less than that of the 110-volt switchboard. These figures, therefore, call for a generator of 15x45 = 675 watts capacity. Some reserve of power is desirable in such a machine for the operation of flatirons, etc. Hence a 1000-watt or 1-kilowatt generator is chosen. This will require a 2 horse-power engine.

The following is the estimate.

2 h. p. engine, 1 kw., 45-volt, shunt wound generator belt, and accessories	$200.00
Switchboard, complete with instruments, resistances, etc	100.00
Wire and conduit for generator and battery	3.50
16 cells of storage battery	200.00
Battery rack (home made)	6.00
Material for power house	8.00
Material for dwelling	92.90
Material for barn	37.85
600 ft. No. 8 weatherproof copper wire	13.00
Poles, insulators, etc.	4.80
Nails, screws, solder, tape, etc	5.00
Labor	80.00
Total estimate	$751.05

Lighting Only; House. Consulting the lighting schedule, it is noticed that about 11.5 ampere-hours are required for the house illumination based on the 110-volt plan. Based on the 30-volt plan, 16 cells of 40 ampere-hours capacity (5 amp. normal discharge) are required, exclusive of any motor load. This may be purchased for about $100.00. The engine and generator listed above should be used here since a smaller outfit might not prove satisfactory and the cost is practically the same. Besides a reserve of power is assured. The estimate is given below.

Engine and generator with belt and accessories	$200.00

Switchboard complete with instruments, resistances, etc	100.00
Wire and conduit for generator and battery	3.50
16 cells storage battery	100.00
Battery rack (home made)	5.00
Material for power house	8.00
Material for dwelling	92.90
500 ft. No. 8 weatherproof copper wire	11.00
Poles, insulators, etc	4.00
Nails, screws, solder, tape, etc	5.00
Labor	54.00
Total estimate	$583.40

Summarizing, the approximate costs of the completed installation are as follows:

6 kw. installation for lighting and power (110 volts)	$1485.00
3 kw. installation for lighting and power (110 volts)	1200.00
Installation for lighting house and barn (30 volts)	750.00
Installation for lighting house only (30 volts)	585.00

These estimates do not include the cost of a separate structure for housing the plant nor the freight charges, which are variable.

EXTRAS.

Vacuum cleaner with attachments	$100.00
Washing-machine complete with wringer and motor	50.00
8-inch fan motor	11.00
6 lb. electric flat-iron	5.00
Sewing-machine motor with attachments	20.00

An electric bell equipment for house and barn, as suggested by Fig. 21b, may be obtained at a cost of about $10.00. This includes twisted pair weatherproof wire to the barn, ordinary annunciator wire for the house, two bells, two push buttons, insulating staples, and three dry cells. The cells should last a year or two. When worn out they should be thrown away and a new set purchased. New cells will cost about 30c each. The wires to the barn may be strung on the poles carrying the power wires.

ORDERING APPARATUS AND TESTING

The first procedure before ordering apparatus is to ask for quotations on the several pieces of machinery, apparatus, and supplies from a number of responsible firms—the more the better. These quotations in the case of engine, generator, power motor, and even storage battery, should be subject to written guarantee and test. No firm which feels certain of the quality of its output will object to a fair guarantee backed by test. The quotations in every instance should be itemized. This will permit of choosing the best bargain in every case, and a considerable reduction in cost may be effected. But mere cheapness in cost is not the only factor to be considered. A larger outfit naturally costs more and this fact should not be lost sight of in arriving at a decision.

In securing prices on wire, fixtures, lamps, and other supplies, it is well to make out a number of copies of a detailed list and get quotations from each of several electrical supply houses. Illustrations of fixture styles should be called for, and a choice made from these. The required amount of wire is readily estimated from the plans of the house on which have been located the light and switch outlets.

The guarantee should cover the satisfactory operation of the machines and the horse-power rating. Unfortunately in these days of close competition it is all too easy to stamp a certain horse-power or kilowatt rating on the name-plate, but it is another matter to prove it up. It is not intended to convey the impression that the practice of over rating is a frequent evil that is apt to creep in anywhere and at any time. But such practice is not unknown and it is desirable for the purchaser to test the plant to his own satisfaction. It is out of the question to make any refined series of acceptance tests in a locality remote from expert advice, testing apparatus, and instruments but a few sample tests may be made as suggested below.

The engine should be tested for horse-power and steadiness of speed; the generator for heating, sparking at the brushes, and ability to hold up its voltage under load; the power motor for heating, sparking at the brushes, and ability to hold up its speed under load; the storage battery for ability to discharge for eight hours at its normal rating. Excessive heating is detrimental to the generator windings; excessive sparking is destructive to the commutator and brushes; while inability to keep up the voltage or speed results in poor service.

Satisfactory operation can be checked up only after a lapse of some time and it is advisable to have some reasonable interval agreed upon, say a month after the installation of the plant, before final payment is made.

Fortunately the engine may be tested in connection with the generator if its power rating is just right, for loading the generator to full load would also load the engine to approximately its full load. After the plant is in running condition, full load current is taken from the generator, care being taken to keep the voltage as read by the voltmeter at exactly the value stamped on the name-plate. Some apparatus must be provided to receive this heavy current. A water rheostat, as described below, serves this purpose. The scraped end of a large sized rubber covered copper wire is bolted to a fairly heavy iron plate which is lowered to the bottom of a barrel filled with water. Another similarly equipped plate is suspended in the water near the top of the barrel, by means of a frame support. The free ends of the wires are temporarily connected to the generator switch terminals in such manner as to be disconnected from the generator when the switch is open. After the generator is running and the voltage is adjusted to its correct value the switch is closed and the top plate in the barrel cautiously lowered. It is advisable not to lower it farther than about half way down. If at this point the ammeter does not indicate full load current, a little—a very little—common salt is sprinkled into the water and given time to dissolve. Salt should be slowly added in this manner until the ammeter indicates full load current. The ammeter reading should be closely watched and any deviation from normal full load should be corrected by raising or lowering the adjustable plate. All this time the voltage as it tends to fall should be raised by turning the rheostat handle at the switchboard. The run, which may take several hours, should be kept up until the generator gets no warmer. This condition is indicated by two unmounted thermometers with small bulbs fastened to the parts of the generator. Such thermometers cost but little. The bulb of one is placed against a field coil and covered with a small wad of waste to keep out the cooling air currents; another is securely fastened with its bulb very near but not touching the armature or revolving part. This will receive the warm air blast from the moving portion. A third thermometer which is to indicate the temperature of the surrounding air is hung near the generator, but not too close, and should be shielded from draughts of air. When the thermometers on the machine no longer increase in reading, the run is finished and the engine should be stopped. Temperature readings are quickly taken of all parts of the machine, including armature surface, commutator and bearings. The armature and commutator readings are taken by laying the thermometer bulbs flat on the surface under a small wad of waste and waiting a minute or two before taking observations. The bearing temperatures are taken by placing the bulbs in the oil wells. The last reading of the field coil temperature before the engine was shut down constitutes the information for this part. In order that the heat run should have proved satisfactory the temperature readings at the machine should not have been higher than the temperature of the surrounding air by the following amounts:

Field coils and armature ....90 degrees Fahrenheit
Commutator and brushes ....99 degrees Fahrenheit
Bearings and other parts ....72 degrees Fahrenheit

During the test the commutator should be closely watched, and if the brushes have been shifted to their best position, there should be very little sparking. If the generator is compound wound and the speed remains steady, the voltage should not lower after it is adjusted before the load is put on. If shunt wound, there should be no trouble in bringing the voltage back to normal value by means of the rheostat.

The engine in the meantime should be watched. It should run easily when the generator is fully loaded. The speed should be counted both at no load and under full load, and the difference should be not more than three per cent. Should the engine materially lower its speed or indicate any distress while carrying full generator load, it is probably too small for the purpose.

There may be a little difficulty in supplying a mechanical load for the power motor, unless a line shaft with a number of belted machines and tools is at hand.

In any event, the full load current for the motor in question should be ascertained. The motor then should be belted to the line shaft and run by the power of the generator. Care should be taken to note that the generator is not furnishing current for any other purpose. The switchboard ammeter will then indicate the current supplied to the motor. The load on the line shaft is varied until the ammeter indicates the rated current of the motor. From this point on the test is exactly similar to the one performed on the generator (for the two are in reality like machines) except that the *speed* of the motor when running idle and when fully loaded is observed in place of the voltage. The correct voltage should be supplied to the motor by adjusting the generator rheostat at the switchboard. If the heating of the parts and the condition of sparking comes within the

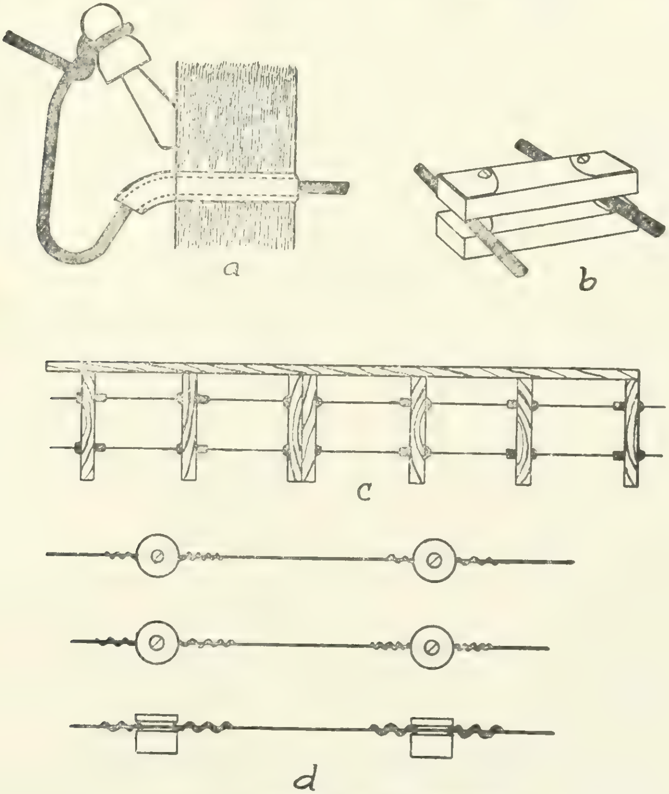


Fig. 27—Wiring Detail Suggestions

prescribed limits indicated above and if the speed at full load is less than ten per cent lower than that at no load, the motor may be considered acceptable.

The storage battery test is more simple. After the instructions as to charging are carefully followed out, it is but necessary to turn on as many lamps in the house or barn as will cause the battery to discharge at its regular 8-hour rate. For instance, if the battery is of 36 ampere-hour rating, this means 4½ amperes on the 8-hour basis. Therefore enough lamps should be turned on to allow 4½ amperes to flow. If the battery can maintain this current for eight hours without the voltage of each cell becoming less than 1.8 volts at the end, the rating is correct. But if the voltage falls below this point before the eight hours are up, the rating is not correct and the battery switch should be opened immediately. It is injurious to the battery to discharge below this point.

POINTS ON INSTALLATION AND WIRING

Engine and Generator. The engine should be bolted to a substantial concrete foundation. Ordinarily this is not necessary for a small capacity generator, but it should have a firm floor underneath.

Both machines should be carefully lined up so that the belt will run exactly over the center of each pulley.

The gasoline tank is preferably buried out of doors and the fuel pumped to the engine as needed.

See that the brushes on the generator press firmly yet freely on the commutator so that when lifted and released they "click" back to the commutator. Be particular to see that they rest squarely on the commutator and not merely on an edge. If the latter is the case a piece of sand paper (not emery cloth), rough side out, placed around the commutator and rotated back and forth a few times under the brush, will give it the proper shape. Also see that the brushes are spaced at exactly equal distances apart around the commutator.

Follow carefully the directions as furnished by the engine and generator manufacturers.

Storage Battery. The remarks made here are adapted from published instructions and refer in a general way to all storage

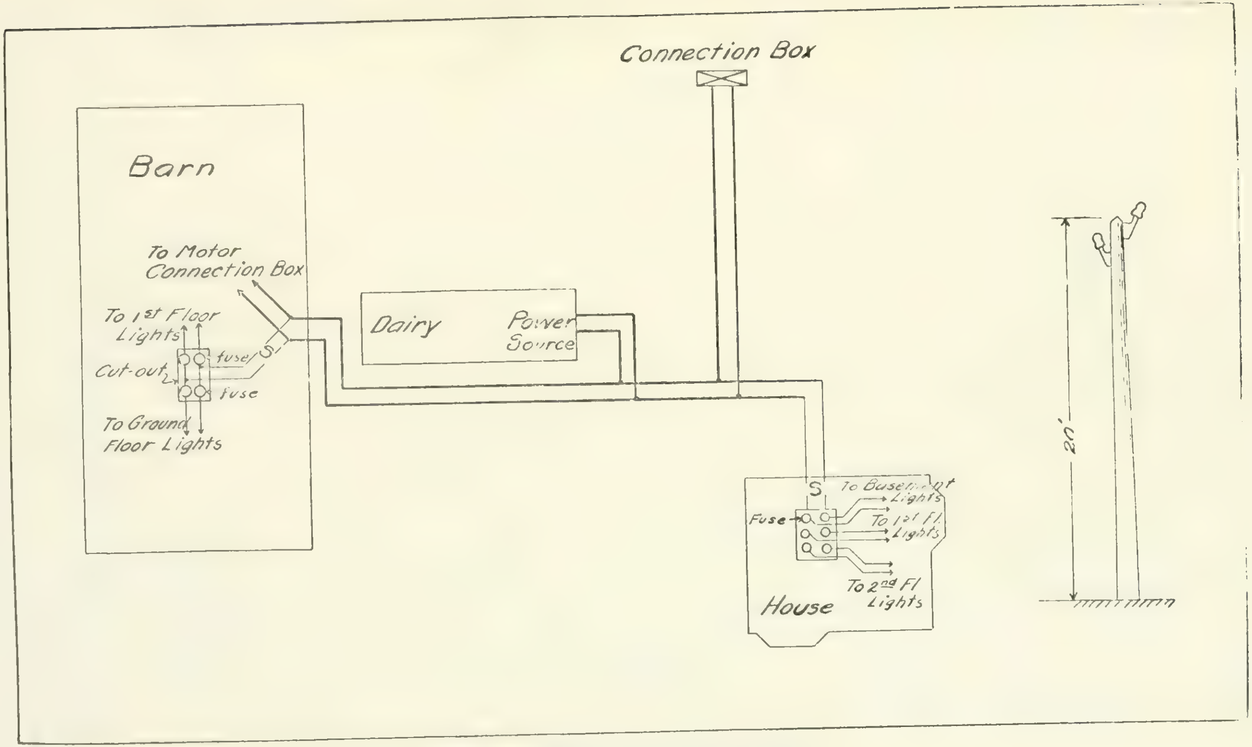


Fig. 28—Distribution Plan for Farm

batteries, but the specific instructions sent with the particular battery installed should be followed.

1. Obtain from the manufacturers the specifications for the battery rack and build it exactly as specified. This is important since the rack must be strong, substantial, and should offer plenty of clearance for the cells for convenience of inspection, tests, etc. If the rack is in two tiers, there should be sufficient clearance between the top shelf and the top of the lower tier of cells to allow for the insertion of hydrometer and for the replacement of electrolyte. A foot of clearance is probably sufficient. Figure 29 illustrates the construction of a typical rack of approved design.

The lettering refers to the following:

A. Copper conductor.
B. Lead terminal lug.
C. Lead covered bolt connector.
D. Glass hold-down.
E. Positive plate.
F. Negative plate.
G. Glass jar.
H. Wood separator dowel.
I. Wood sand tray.
J. Glass insulator.
K. Rail.
L. Iron bolt.
M. Spacing block.
N. Cross tie.
O. Dowel pin.
P. Brace.
Q. Upright.
R. Vitrified brick.
+ Positive lug.
— Negative lug.

The rack and battery should be located in a room which is dry, of moderate temperature, and well ventilated. The temperature should be kept above 50 degrees Fahrenheit for best results. Extremes of temperature affect the proper working of

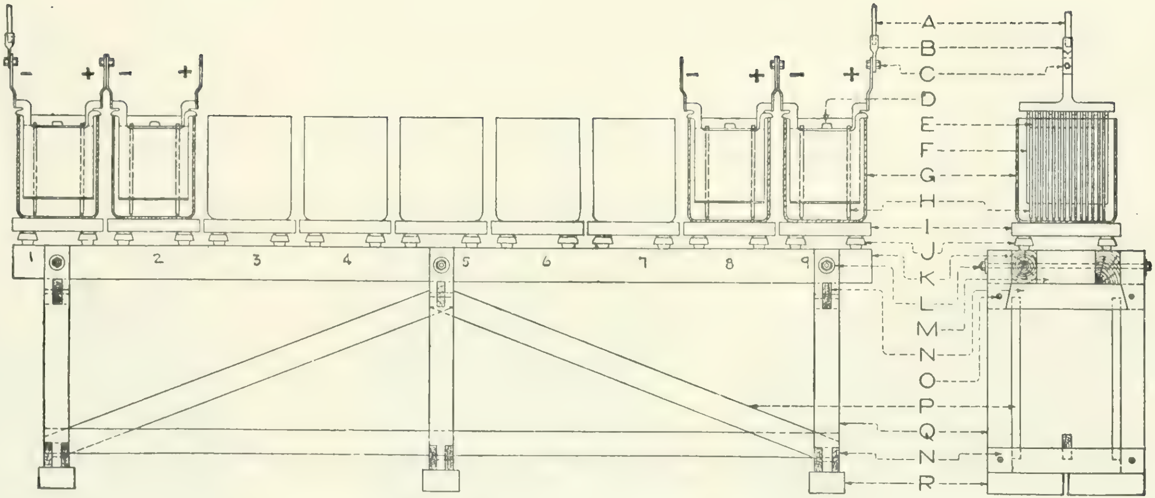


Fig. 29—Typical Storage Battery Rack Construction

a battery. It is well to have a stove in the battery room during the cold months.

Soon after arrival the cells should be carefully unpacked and assembled according to the directions furnished with them. The wood trays are placed on the insulators furnished for the purpose and then filled level with fine sand. The jars are then placed on the sand, after which the elements are placed in the jars, the brown or positive plates alternating with the gray or negative plates. Figs. 30a, 30b, 30c, illustrate the process of assembling the plates. Care must be taken to have the *positive* lug of one cell adjacent to the *negative* lug of the other in order that when bolted together, a positive and a negative lug may be joined, thus putting all cells in "series." Failure to follow this precaution, besides resulting in injury to the cells in question, causes the voltage to be reduced owing to the voltage of a part (one or more cells) opposing the remainder.

The electrolyte is next poured into the cells until a level of ½ to ¾ of an inch above the top of the plates is reached. This electrolyte, which is pure sulphuric acid of about 1.210 specific gravity (where water is taken as 1.000), usually comes with the cells and is included in the price. It is better to procure this acid from the Storage Battery Company because it is especially prepared for the purpose. Commercial acid or hard water will ruin the battery in time. Should conditions arise where it becomes necessary to prepare the electrolyte on the premises, the directions furnished by the company should be scrupulously followed.

Always pour the acid into the water, and not water into acid. This is in the proportion of one part of pure concentrated acid (1.840 specific gravity) to four and a half parts of distilled water. (Clear rain water will do). A metal vessel must not be used for the mixing.

The battery is now ready to be connected up for charging. All the wiring, from both the generator and battery, should be carefully made according to diagram. Particular care should be exercised to see that the positive terminal of the battery in every case connects with the positive terminal of the generator.

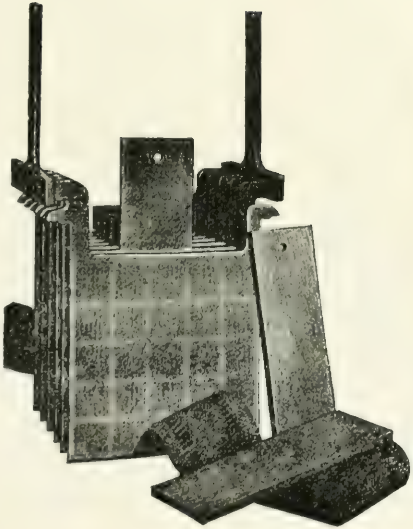


Fig. 30a

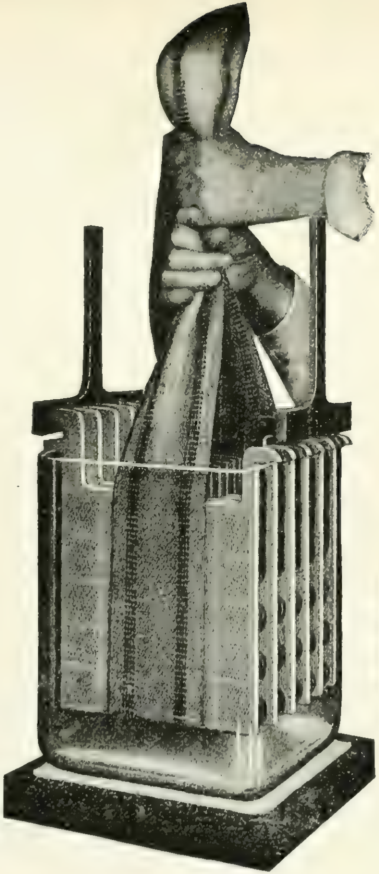


Fig. 30b

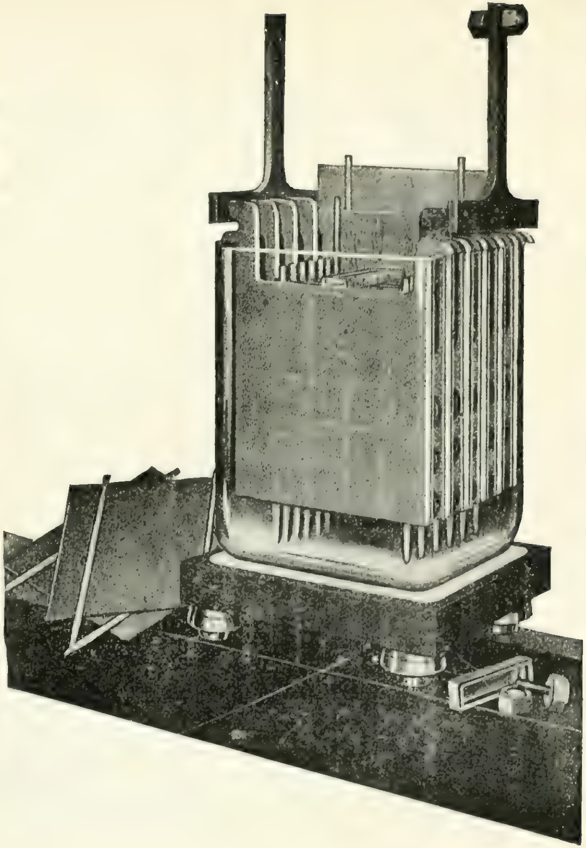


Fig. 30c

This is insured by test, using the switchboard voltmeter. When ready, the generator is run and allowed to build up to a certain voltage. Two small wires are connected, one to each terminal of the voltmeter. The free ends are then touched to the main switch terminals leading to the generator. If the reading is backwards, the wires should be crossed over and again touched to the switch terminals. When the reading is up on the scale, *that* voltmeter terminal marked (+) or positive is noted, and the switch terminal to which this positive voltmeter terminal is connected by means of the small wire, is the (+) or positive terminal of the generator. On charging, it is imperative that the positive terminal of the battery (free end of the brown plates of the end cell) be connected to *this* switch terminal. The negative battery terminal (free end of the gray plates of the other end cell) then connects to the other switch terminal.

Wiring. It is supposed that when preparing to wire, the services of competent wiremen will be secured from a neighboring city or town. But in all probability inspection will be of necessity performed by the owner himself. The instructions given are to aid him in this respect, since proper wiring is a very important part of the installation.

All wires from the generator to the switchboard are preferably run through conduit under the floor in order to have them out of the way. The ends of the conduit should bend up through the floor and the inner edges be filed away to avoid danger of cutting into the insulation of the wire. If the battery is near the switchboard the wiring from it may be neatly carried on porcelain insulators along the wall. All lugs to which wires are to be connected should be carefully brightened with sand paper in order to insure good connection and all joints should be soldered and taped.

Where the main wires leave the power room, and where the wires enter the house and barn a construction similar to Fig. 27a should be employed. The outside wires are held by bracket insulators firmly fastened to the outside wall. From here the wires form "drip loops" and then enter the building through curved end porcelain tubes. Moisture collected all along the wires, sheds to the ground at the drip loops and the downward curve of the tube prevents this moisture entering the building along the wire.

Figure 28 is a schematic diagram of the outdoor wiring arrangement. The necessary poles, one of which is illustrated in this figure, are placed so that the wire spans will not exceed 120 feet. Each pole is about 25 feet in length over all and should be planted five feet in the ground. No pole is necessary near the buildings. The wires are fastened to the insulators by short pieces of the same wire in a manner suggested by Fig. 27d. The wires lead to the cut-out cabinets in the house and barn, where they branch off to the several circuits as indicated in Fig. 28. But first of all, they should go directly to switches in the cabinets and all the branch circuits should be fused. The motor circuit which leads to the connection box has no switch but the connection box is fused. Both boxes should have slate backings with the electric terminals fastened to the slates. The box in the barn is preferably of cast iron and may be purchased at a supply establishment. The one out of doors may be home made of wood, lined with sheet asbestos paper.

The best style of wiring for the interior of the house is what is known as "concealed." That is, the wires are run between the ceiling and floor above, and in the partition walls. If the house is already built and it is not very convenient to take up some of the flooring for this purpose, wooden moulding may be used to receive the wires, and be so fastened to the ceiling and walls as to make it as inconspicuous as possible. The mouldings are long varnished strips of wood made up in two parts, the *backing* which is grooved to receive the wires and the *capping* which when fastened in place, hides them. But exposed work is unsightly and concealed work is advised for all parts of the house except the basement. The best time to wire a new house is before the lath is placed on the walls and ceiling.

Figure 27c shows the manner of stringing wire through joists. Holes are bored just large enough to receive the porcelain tubes and the wires are strung through the tubes.

For open work as in the barn or basement, two wire porcelain cleats, Fig. 27b, may be used if the wires are not too large. For heavier wires in open work, such as the power circuit in the barn, porcelain knobs, Fig. 27d, are used. All open wires should be not less than 2½ inches apart and the distance from the surface wired over not less than ½ inch.

Never allow any wire to be supported on anything but the insulators. In concealed work, the wire should be separated from the surface wired over by at least one inch, and where running along a joist, knobs, Fig. 27d, or special single wire cleats which hold the wire one inch from the wood, are used. The wires should be kept at least five inches apart.

Wires should be supported at least every four and one-half feet. If the wires are liable to be disturbed this distance should be shortened.

Wherever the wires must come together, as at outlets for lights and switches, each wire is separately encased in flexible insulating tubing extending as far back as the last supports.

If in concealed work, porcelain insulators cannot be used in certain inaccessible portions of a house, making it necessary to "fish" for the wires, each wire should be separately encased in flexible insulating tubing extending back to the last support. This tubing should be applied in continuous lengths.

All wire joints must be carefully soldered and taped. This should be insisted upon. A neglected joint is certain to cause trouble sooner or later.

Figure 31 illustrates the diagram of connections of a motor with its starting box, to power. In the case of the 6 h. p. motor, the power leads, indicated by the arrow heads, connect to the terminals of the connection box. In starting the motor, the switch is closed first, then the handle of the starting box is gradually moved over until the small magnet (shown in the lower right hand corner of starting box in the figure) holds the lever in place. To stop the motor, open the switch.

MISCELLANEOUS STATEMENTS

The rules for the operation and care of the several pieces of electrical apparatus are sufficiently set forth in the directions sent out by the manufacturers, and when backed by common sense, no grave difficulties should be experienced. But it is very desirable to have a regular schedule laid out as far as possible for the time of operation of the engine and generator, and the charging of the battery. An ideal arrangement would be to

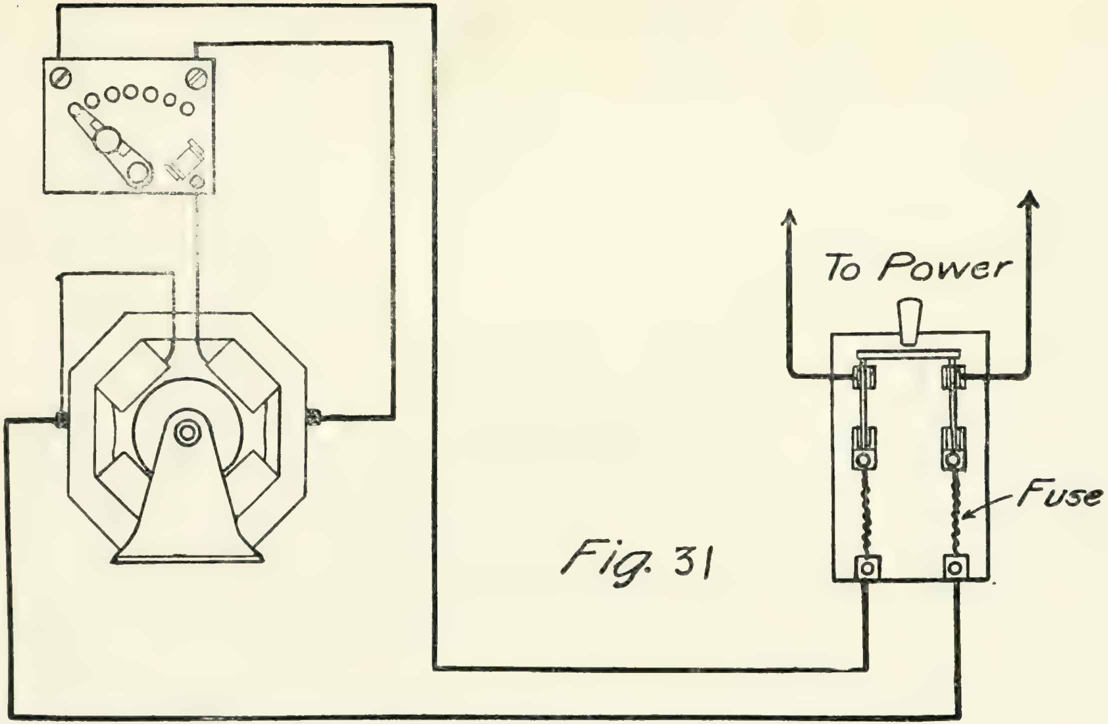


Fig. 31

Fig. 31—Typical Wiring Diagram of Motor with Starting Box

run the line-shaft, pump the water, charge the battery, operaate the vacuum cleaner and flat iron, all at the same time, leaving only the 6 horse-power motor to be operated on a separate occasion. Of course this ideal arrangement can seldom be realized in practice, but as close an approximation as possible should be the daily schedule.

If, because of an evening entertainment, a large number of lights are in use at one time, it is best to run the engine for the occasion so as to relieve the battery.

Instructions for Daily Operation. If it is desired to run the line shaft alone, the generator belt is removed. If it is desired to supply the electric power to the larger motors, the generator is brought up to speed, its voltage adjusted to normal value, and the main power switch closed. If it is desired to charge battery only, the battery switch or switches are closed and the power switch left open. Never close the battery switches until the voltage of the generator has been adjusted. The amount of charging current is controlled by the rheostat on the switchboard. The handle is turned one way or the other to secure this result. Of course the daily routine of charging should not be attempted until the manufacturer's instructions as to initial charge, have been carefully carried out. If it is desired to supply some outside power as well as to charge the storage battery, all the switches mentioned above are closed. If it is desired to supply only storage battery power, as for evening lighting, the main power switch is left open.

Never attempt to discharge a battery below 1.8 volts per cell. To find out what each cell is doing it is desirable to have the switchboard voltmeter provided with a double scale, the second scale to indicate about three volts full deflection. With flexible leads from this voltmeter to the battery, each cell may be tested for voltage.

Though it is not necessary to deny oneself good illumination it is also unnecessary to be extravagant with the lighting. The plant designed for extravagance is expensive in first cost as well as in operation.

Operating Costs. It is rather difficult to state in general the cost of light and power produced as outlined in these pages.

Such cost includes the price of gasoline, the cost of maintaining the storage battery, some oil, and miscellaneous repairs on the machinery. The last two items are usually small. The life of the battery depends on the care it receives and may average 5 years. The main operating expense is for gasoline. The sizes of gasoline engines referred to in these pages, will operate on between a sixth and an eighth of a gallon of fuel an hour for each horse power when running under full load. At a third load these figures will about double. Hence, assuming gasoline at 16c per gallon, the cost of fuel for one horse power for an hour will vary between 2c and 5c depending on the load. The immediate cost of using a 25-watt lamp on this basis, varies from 0.12 to 0.3 of a cent per hour. After considering all the other items of cost, it is probable that the average cost during the year need not exceed the price of the same amount of electrical energy in the city.

BULLETINS OF THE ENGINEERING EXPERIMENT STATION

*No. 1. The Iowa State College Sewage Disposal Plant Investigations.
*No. 2. Bacteriological Investigations of the Iowa State College Sewage.
*No. 3. Data of Iowa Sewage and Sewage Disposal.
*No. 4. Bacteriological Investigations of the Iowa State College Sewage Disposal Plant.
*No. 5. The Chemical Composition of the Sewage of the Iowa State College Sewage Disposal Plant.
*No. 6. Tests of Iowa Common Brick.
*No. 7. Sewage Disposal in Iowa.
*No. 8. Tests of Dry Press Brick Used in Iowa.
*No. 9. Notes on Steam Generation with Iowa Coal.
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Vol. IV. No. 5. Sanitary Examination of Water Supplies.
Vol. IV. No. 6. Sewage Disposal Plants For Private Houses.
Bulletin No. 25. Electric Power on the Farm.

* Out of print.